From the Publishers of NASA Tech Briefs

LASER TECH BRIEFS

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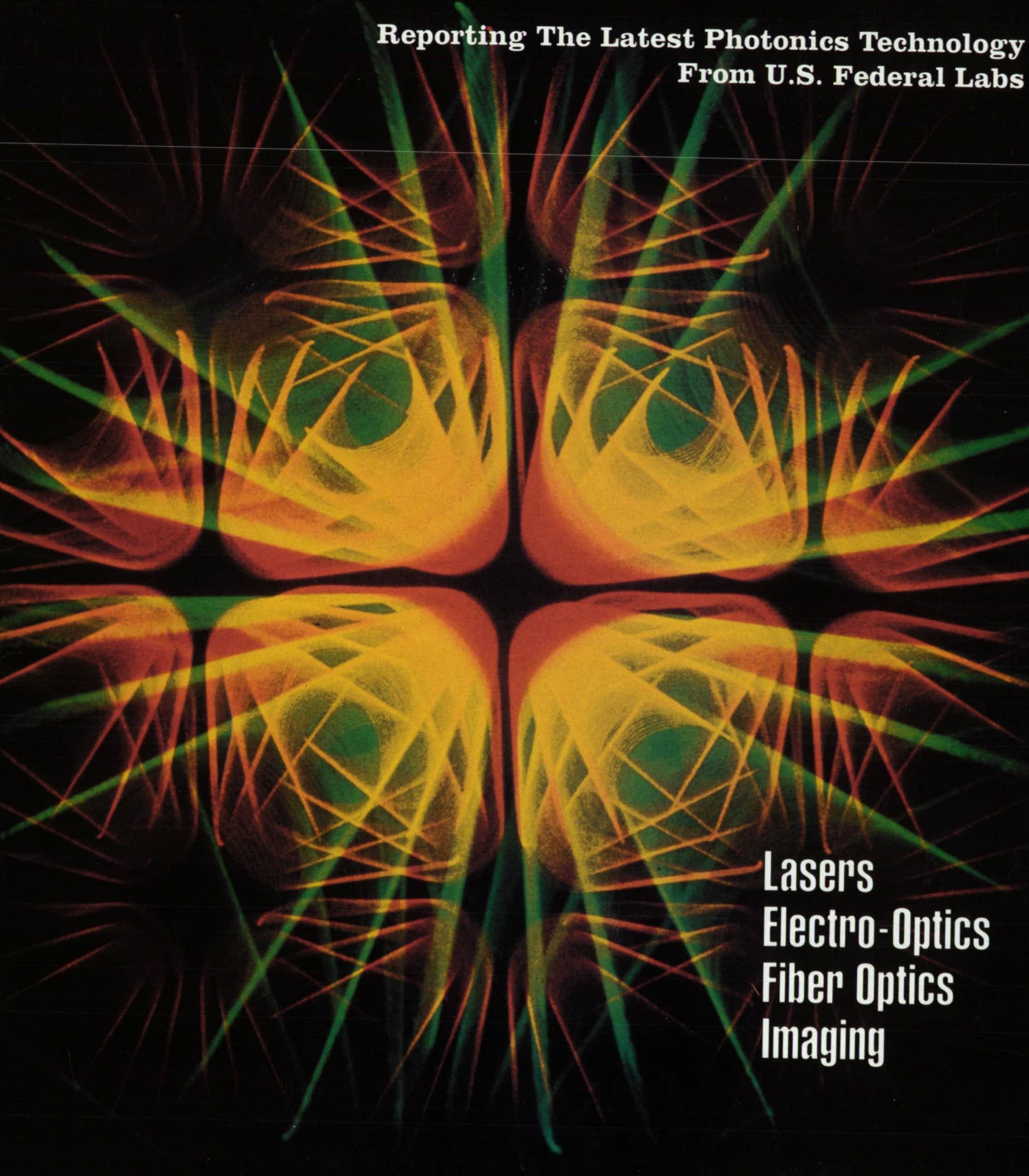
Reporting The Latest Photonics Technology
From U.S. Federal Labs



Lasers
Electro-Optics
Fiber Optics
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Welcome

to the first edition of Laser Tech Briefs.

Bill Schnirring
Publisher

Since the value of technology is directly proportional to the speed with which that technology is transferred, both NASA and Associated Business Publications (publishers of *NASA Tech Briefs*) want to bring you new technology ideas as quickly as possible. To help achieve this goal, we've created *Laser Tech Briefs* to report more innovations in photonics — including lasers, electro-optics, fiber optics, optics, and imaging — than we would otherwise be able to do in a regular issue of *NASA Tech Briefs.*

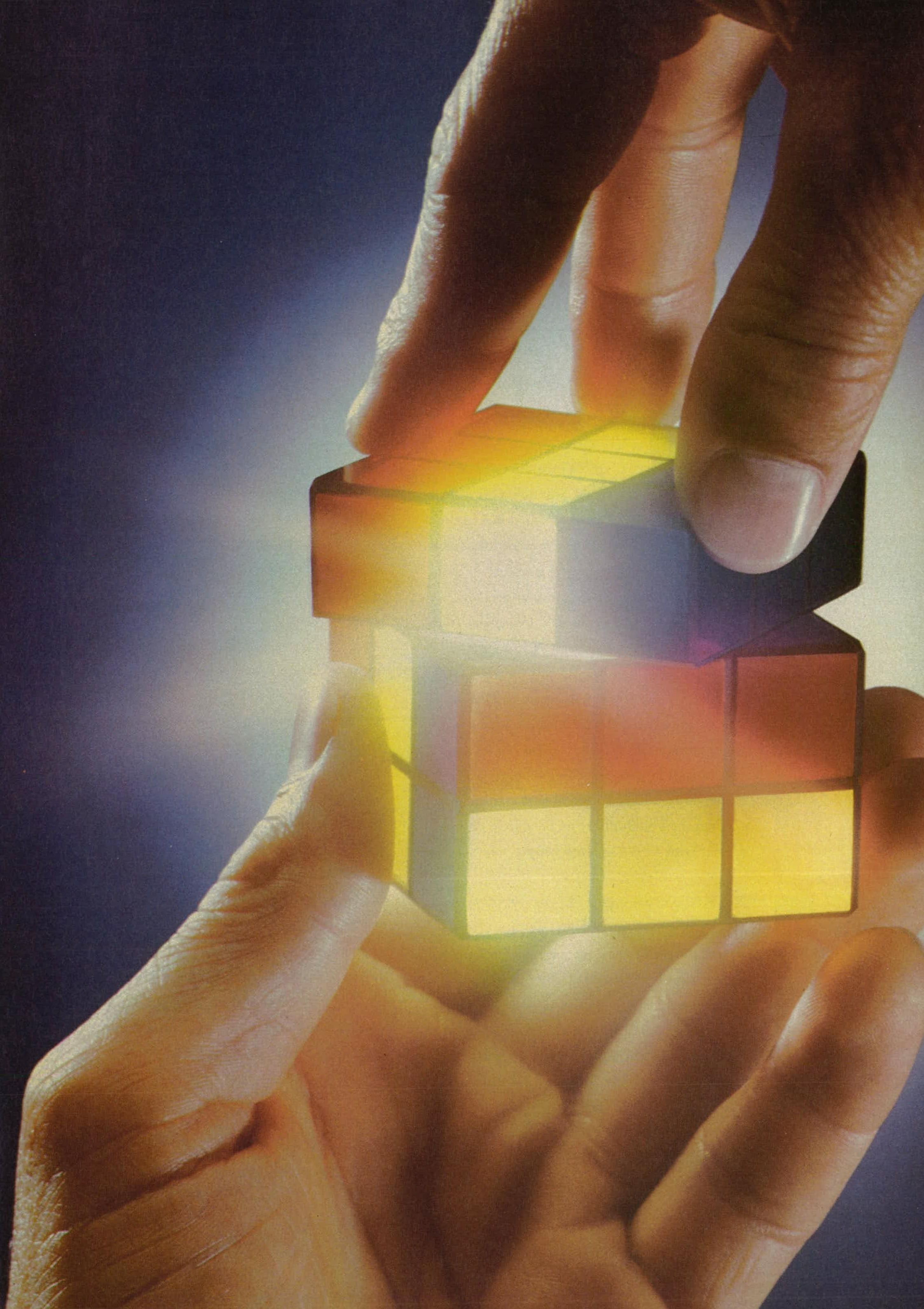
Not everyone who subscribes to *NASA Tech Briefs* will get a copy of LTB. You have been chosen to receive the new magazine because you previously indicated an interest in lasers/optics when you filled in your *NASA Tech Briefs* qualification card. The circulation of this initial issue of *Laser Tech Briefs* is 40,000, as compared with the 200,000+ monthly subscriptions to *NASA Tech Briefs*, which now has become the second-largest engineering magazine in the world, thanks to the interest of you and your fellow engineers, scientists, and technology managers.

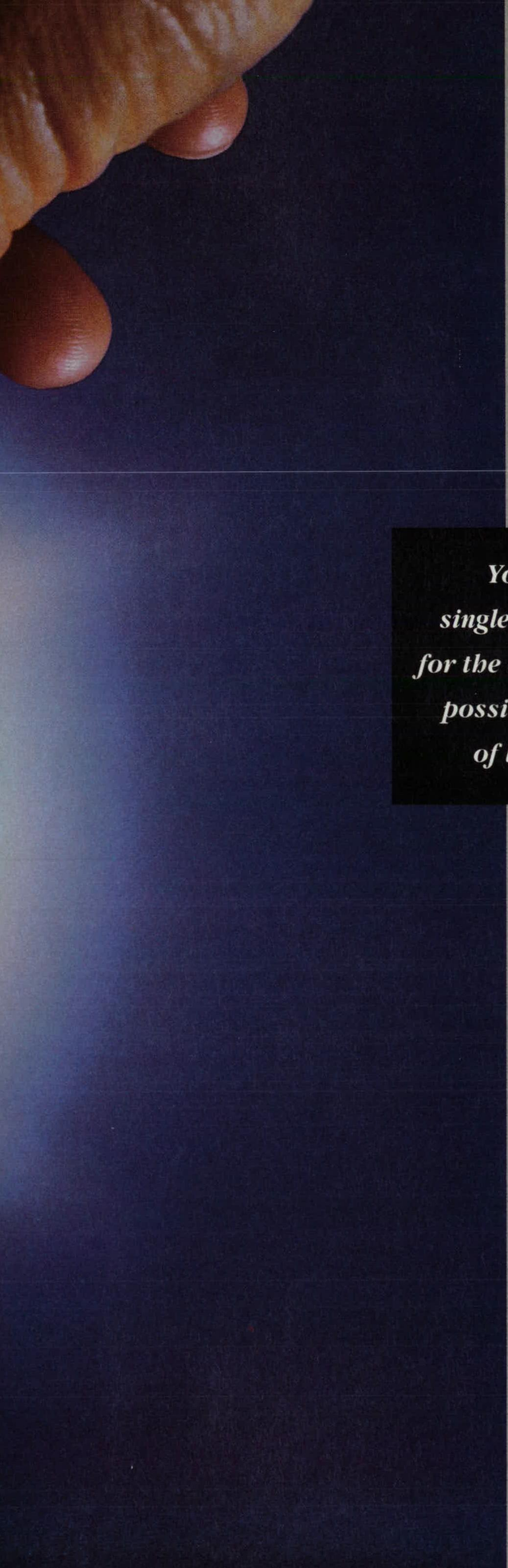
Just as we solicit your comments about *NASA Tech Briefs* by providing the "Feedback" portion of the reader service card in every issue, we're equally interested in your comments about the new publication you hold in your hands. Hence we've asked for your comments on the card in this issue.

If your reaction is as favorable as we hope it will be, we will bring you this magazine quarterly in 1994. We plan to expand the scope of the editorial coverage to include activities and breakthroughs in photonics that are happening in other government agencies, as well as the continuing work at NASA. With over 700 federal laboratories nationwide, there's a treasure-trove of new technology out there, and we want to bring the best of it to you.

If you'd like to receive *Laser Tech Briefs* quarterly in 1994, please complete the qualification card on page 33 of this issue. We've included a second card (page 67) for you to pass on to a colleague. Hope you enjoy LTB. Thanks.

Bill Schnirring





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LASER TECH BRIEFS

SEPTEMBER 1993
Vol. 1 No. 1

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THE HIGHEST POWER MOST RELIABLE LASER DIODES AVAILABLE

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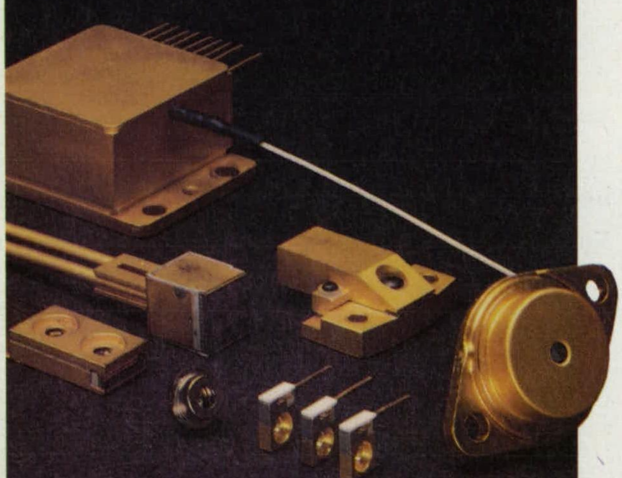

For more information on laser diodes and laser diode systems, call us at (408) 943-9411 or write: Spectra Diode Labs, 80 Rose Orchard Way, San Jose, CA 95134, U.S.A.

Spectra Diode Labs

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BRIGHT PROSPECTS FOR LASER TECHNOLOGY

Work at five NASA research centers seeks to broaden applications for advanced lasers and optical components. Under investigation is this swiftly evolving technology's role in high-speed computation, space communications, and global weather and climate prediction.

Ames Research Center

LASERS AND OTHER OPTICAL DEVICES ARE AT THE HEART OF A wide variety of systems currently employed at Ames Research Center. They are applied in two broad domains for aerospace research: metrology, the measurement of physical parameters, and computation, the use of optical systems to perform analog calculations.

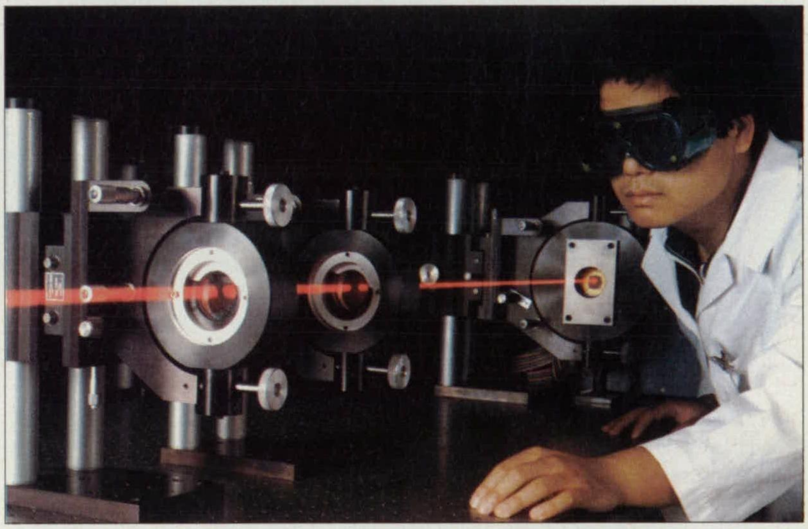
Metrology applications include laser velocimetry for the measurement of air flow during wind tunnel testing of aeronautical models, fiber-optic sensors to read acoustic signals generated during such testing, and the use of laser diodes to measure atmospheric characteristics. Lasers also are employed in three-dimensional scanners for accurate comparisons of wind tunnel results with simulations from Ames' fluid dynamics computations.

Optical computation technologies under development take several forms. Optical correlators are being applied to autonomous vision for robotic vehicles, and optical matrix processors are enabling linear analysis of large high-throughput data sets. New holographic materials may form the basis for dynamically reconfigurable optical interconnection networks for communication and computation.

A closer look at one of these illustrates the range of optical devices in Ames' research programs. An increasing number of current or planned NASA missions either produce, or require the analysis of, very large amounts of information. Examples include the analysis of the space shuttle main engine plume for anomaly detection, analysis of remote-sensing multispectral satellite images, and the vibration control of large structures in space. All of these involve the rapid solution of large-matrix equations. Optical processing can ease the problems of dealing with such high-throughput data flows.

An optical matrix processor is an analog optical computing system that uses light to multiply an input vector by a matrix in one massively parallel operation. It consists of six major optical components—beginning with a light source, such as an array of laser diodes. Following that is the critical processing device, a one-dimensional acousto-optic array that converts digital electronic values into analog light intensities. Each digital number is rendered as an analog electrical amplitude, which in turn drives an acoustic input to one of the acousto-optic cells. The amount of light passed by the cell is proportional to the power of the acoustic signal. The array of independent cells represents the input vector.

Next, a cylindrical lens spreads out the light so that the input vector exposes every column of a matrix, an operation implemented by using a two-dimensional spatial light modulator such as a film transparency. Thus the transmittance of each cell of the transparency is proportional to the product of an element of the input vector and an element of the matrix. A second cylindrical lens focuses light from all the rows of the matrix output to a single row, thereby performing



Ames Research Center's optical matrix processor could revolutionize the handling of high-throughput data sets on board spacecraft.

the addition of all vector products. The complete matrix-vector product appears at the output, where a detector array such as a CCD device or a set of avalanche photodiodes reads the results. These analog results can be converted to a digital representation.

Optical matrix processors could revolutionize on-board aerospace computation. The multiplication of a 1000-element vector by a 1000-x-1000-element matrix at the rate of 1000 times per second, feasible with an optical matrix processor, yields one trillion operations per second. Optical processors are light, small, and consume minimal

power, making them ideal for on-board applications. A flight-qualified optical matrix processor could reside in a compact, block-optic system occupying less than 200 cubic centimeters, weighing less than 1 kilogram, and requiring a power input on the order of only 10 watts.

Goddard Space Flight Center

THE ROOTS OF GODDARD SPACE FLIGHT CENTER'S LASER program go back to the early 1960s, when Goddard scientists began a laser ranging program to the moon and Earth-orbiting satellites for precise orbit and distance measurement—an effort that continues under the Dynamics of the Solid Earth (DOSE) program, but with a different mission. Now Goddard puts its detailed understanding of the geoid to work using laser ranging to investigate the motion of the tectonic plates.

Goddard also has been active in laser communications since the early days of carbon dioxide lasers in the 1970s. Today the transmitter of choice appears to be the semiconductor laser, and Goddard, together with Langley Research Center, is funding industry development of high-power diffraction-limited diode laser sources capable of modulation bandwidths in excess of 1 gigahertz.

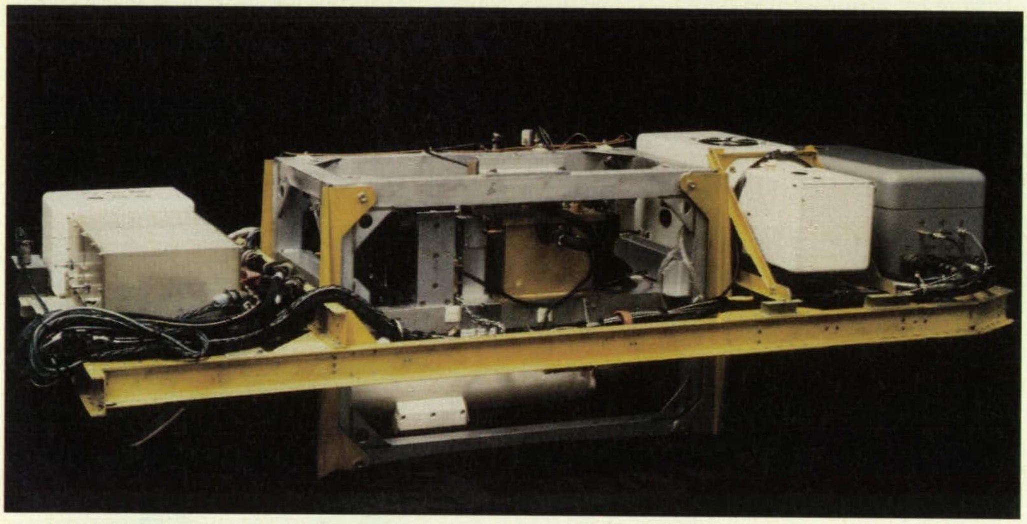
Predominantly a science center, Goddard is active in laser spectroscopy for understanding the properties of planetary and stellar atmospheres and the interstellar medium. Laser sources are required throughout the spectrum from the visible up to submillimeter wavelengths. Research on carbon dioxide waveguide laser-pumped far-infrared lasers, such as the methanol laser, investigates hydroxyl radical emissions at 118 microns in a laser heterodyne receiver.

The submillimeter wavelength region represents one of the most important yet most challenging and unexplored portions of the electromagnetic spectrum. This region is important to the military in remote sensing because submillimeter radiation can penetrate clouds, smoke, dust, and fog. Also, spectroscopy of vibrational and rotational levels of molecules, phonons, magnons, plasmons, and energy gaps in superconductors in these regions will increase knowledge of the basic physics of these systems. Further, this region is important to astrophysicists because only observations here can clarify important processes taking place in interstellar molecular clouds, which may explain the formation of planets and other phenomena.

The heart of the laser heterodyne receiver for these systems is a local oscillator. Currently the only proven local oscillator source above a frequency of 1 terahertz is an optically-pumped submillimeter laser—a gas laser pumped by a carbon dioxide laser. For space and airborne applications it is highly desirable to have an all-solid-state local oscillator source, and in the past year Goddard has been studying various methods of building one. The best method to date is to generate submillimeter radiation by mixing two diode lasers within asymmetric multiple quantum wells. This method promises 0.5 milliwatts of power and less than 400 kilohertz linewidth, frequency stability better than 1 megahertz, and amplitude stability better than 0.5 dB.

Semiconductor laser diodes useful in a variety of commercial and military applications profit from continued advances in epitaxial growth techniques. Goddard researchers are developing semiconductor laser systems for use in space science and engineering projects. One example is space-based optical intersatellite communications. Laser-based transmitters operating at optical frequencies are both smaller and lighter than the microwave transmitters currently used between space-based terminals. In addition, they permit large information transmission capacity. Semiconductor laser technology is approaching the high power levels required (more than 1 watt of optical power) to make such intersatellite links cost-effective.

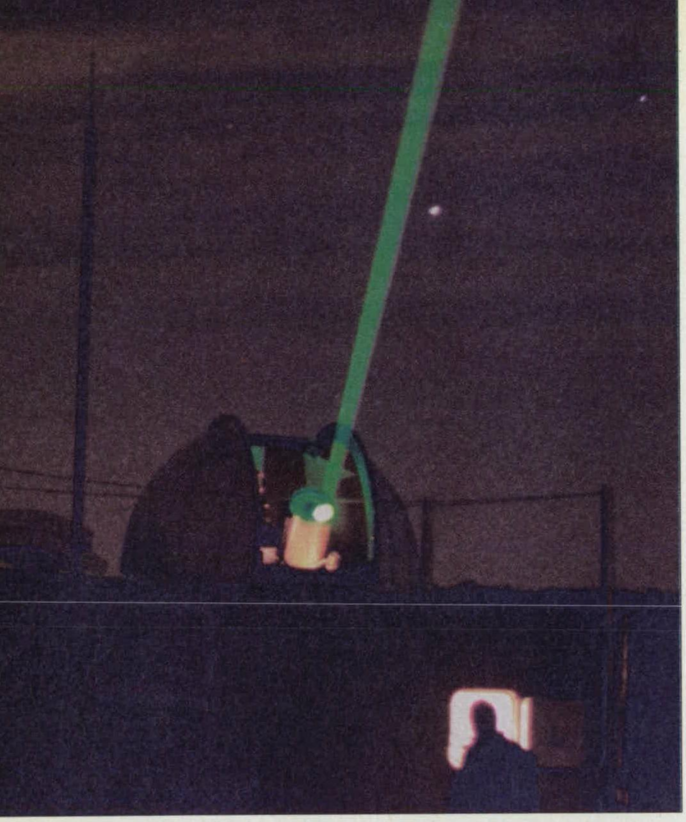
Turning again to the Earth sciences, among Goddard's primary responsibilities is weather, climate, and ocean research, as well as stratospheric chemistry and dynamics studies. This responsibility includes development of new technologies for remotely sensing the state of the atmosphere from the ground, the air, and space platforms. The central remote sensing technology is now lidar (light detection and ranging), which has demonstrated the capability over the past decade to provide range-resolved atmospheric measurements with unprecedented accuracy and spatial resolution. Goddard's Laboratory for Atmospheres is involved in lidar development and operation.



The Cloud Lidar System developed by Goddard Space Flight Center will fly on the high-altitude ER-2 aircraft to measure cloud height, structure, and optical properties.

Temperature is one of the most important atmospheric parameters, and measurements are required in essentially all weather and climate prediction methods. Goddard researchers pioneered the measurement of atmospheric temperature and pressure using the DIAL (Differential Absorption Lidar) technique. This method also is employed in a trailer-based lidar that has been transported to sites around the world to measure stratospheric ozone concentrations with high accuracy.

High-resolution measurements of the Earth's surface topography are now possible with the combination of laser altimeter sensors, Global Positioning System (GPS) receivers, and laser gyroscopes from aircraft and spacecraft platforms. The laser altimeter sensors employ pulsed time-of-flight measurements to determine the two-way range to the surface with a vertical precision on the order of 10 centimeters. The spatial (horizontal) resolution of these sensors is set by the size of the laser pulse's far-field pattern and its repetition rate at the one-to-tens-of-meters level.



NASA Goddard's network of transportable laser ranging stations tracks satellites in support of Earth science applications.

A number of Goddard investigators are working on airborne and space-based laser altimetry. The airborne work involves repeated, multi-year surveying of the Greenland ice sheet. More than 3 x 10^8 individual laser height measurements have been collected since August 1991. Internal consistency of these data has been demonstrated at the 10-centimeter level.

The laser altimeter technology used in the airborne programs has been developed by a combination of direct funding from NASA Headquarters and NASA's Small Business Innovation Research (SBIR) program. A number of manufacturers have contributed to the diode-pumped solid-state laser transmitter technology, receiver optics, and instrument electronics. Goddard also is sponsoring a major technology transfer project with industry in an attempt to commercialize the system of airborne laser altimetry observations for terrain surveying.

The transition of laser altimetry to space-based observations of the Earth and other planets is already under way. The Mars Observer Laser Altimeter (MOLA) is inbound toward the start of a November 1993 Martian mapping campaign on the U.S. Mars Observer Mission. Expected vertical accuracy is 30 meters and horizontal resolution is about 300 meters for this application. Third-generation laser altimeter instruments are planned for the Global Topography Mission (GTM), a joint NASA/Italian Space Agency Earth Probe Mission, scheduled for the turn of the century. The Geoscience Laser Altimeter System (GLAS), an Earth Observing System (EOS) facility instrument, is being developed for launch in 2002. The GTM laser altimeter employs five beams in a pushbroom configuration to generate a contiguous narrow swath of 30-meter spatial resolution and meter-level vertical accuracy for control-point topography of the Earth's land, vegetation, and ice surfaces. The GLAS instrument is optimized for the measurement of ice-sheet mass balance with a vertical accuracy below 10 centimeters.

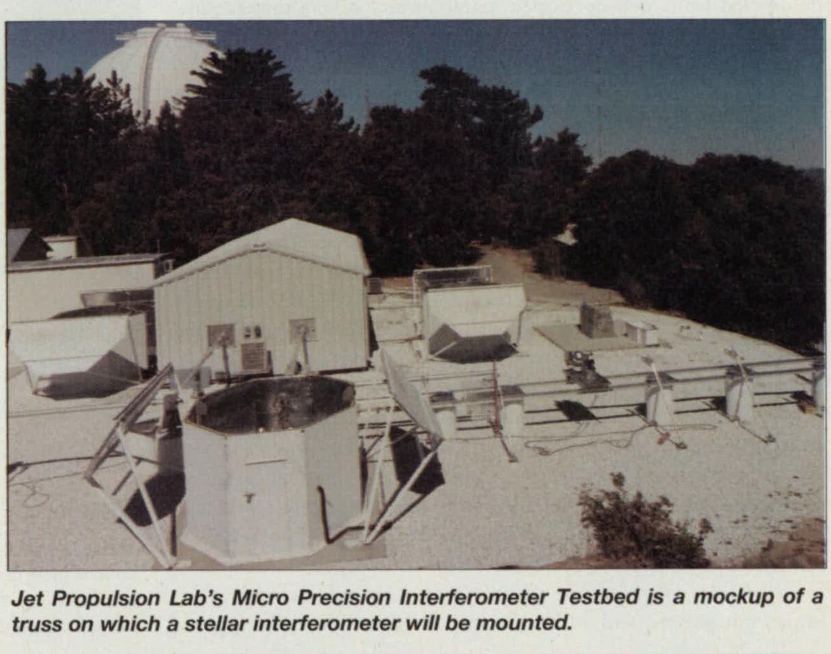
Goddard performed the first successful satellite laser ranging (SLR), or optical radar, experiments to artificial satellites in 1964. Over the past three decades, ranging precision has improved by three orders of magnitude to a few millimeters today. An international network of 43 SLR stations routinely track eight (soon to be 12) satellites in support of several Earth science applications. These satellites range in altitude from 425 kilometers to 20,000 kilometers above the Earth's surface. In addition, a few stations range with centimeter accuracy to five optical reflectors placed on the moon by the American Apollo and Soviet Lunakhod missions.

The global SLR data set is archived in the Crustal Dynamics Data Information System at Goddard. The data first is used by analysts to determine an orbit for the satellite that is accurate to a few centimeters. Once the orbit is determined, station positions are adjusted to determine their locations relative to the center of the Earth to better than two centimeters on a global scale. By making observations at multiple stations over several years, the relative velocities of the tectonic plates can be determined with accuracies of a few millimeters per year. Frictional forces cause the velocities of stations near tectonic plate boundaries to deviate from that of the "rigid" plate, and these modified motions provide insight into the buildup of stress and strain within the plates, eventually released through an earthquake, and the strength of the underlying rock that resists the motion.

Jet Propulsion Laboratory

AT JPL, A RESEARCH TEAM IS USING LONG-BASELINE (100 meters) stellar interferometers for astrophysical research on topics such as the detection of planets around nearby stars, the study of the formation of stars and planetary systems, and very-high-angular-resolution synthetic-aperture imaging of compact astrophysical objects. Currently under construction at Mt. Palomar is a testbed 100-meter interferometer to measure the angles between stars to an accuracy of 30 microarcsec (150 picoradians). A key part of such stellar interferometry is the use of lasers for precise metrology.

Laser metrology for gauging distances between optical fiducial



Jet Propulsion Lab's Micro Precision Interferometer Testbed is a mockup of a truss on which a stellar interferometer will be mounted.

points is one topic of study. An important goal is modifying the standard polarization-encoded heterodyne interferometer to achieve higher accuracy. Commercial systems have a resolution of 1 nanometer and accuracy of 3-10 nanometers. JPL has demonstrated accuracy of less than 2 picometers using a technique called cyclic averaging. In related metrology work, a laser tunable over 15 gigahertz with a frequency that can be set to an accuracy of 15 kilohertz is planned for an absolute metrology system. (Most laser interferometers are incremental systems that measure motion relative to an arbitrary zero point.)

Also under investigation is a surface metrology system. Space-based interferometers will need optical surfaces whose imperfections are known to levels of 0.1-1.0 nanometer. While scanning probe microscopes have such resolution, they are limited to scanning very small (100-micron) areas. For testing larger surfaces, phase-shifting interferometers normally are used. Because of errors in the phase shifter, these units are limited in accuracy to a few nanometers. The JPL team is working on a variation of a phase-shifting interferometer in which the imperfection of the shifter is calibrated out at levels of 0.01-1.0 nanometer.

JPL also is using laser interferometers on the Micro Precision Interferometer (MPI) testbed. The MPI is a 6-meter mockup of a truss on which a stellar interferometer will be built. Laser interferometers are used to monitor and control the optical effects of structural vibrations. The goal is to control optical paths on space-based interferometers at 10-nanometer levels.

The long-term study of atmospheric aerosol backscatter in the 9-11 micron spectral region, where the important carbon dioxide technology operates, has been in process at JPL since 1983. This data set historically has been gathered at two laser wavelengths, 9.25 microns and 10.6 microns, to investigate predicted enhancements in backscatter that arise from spectral resonances exhibited by certain atmospheric aerosol constituents. JPL has developed and flown an Airborne Backscatter Lidar (ABL) on Pacific Ocean survey missions to characterize the atmospheric backscatter over a large and meteorologically important part of the global atmosphere.

JPL's semiconductor laser program is developing space-qualifiable diode lasers for future NASA missions. These applications require a range of laser structures, from simple replacements for flashlamps to sophisticated tunable devices and integrated subsystems. They also cover a wide range of operating wavelengths, some that can be derived from well-developed materials and others that require materials development. The laser work is synergistically supported by a NASA- and DOD-sponsored photonics program aimed at the development of integrated active and passive components for microinstruments and space communications.

Semiconductor laser development at JPL is carried out in the Microdevices Laboratory (MDL), the primary experimental facility for JPL's Center for Space Microelectronics Technology. MDL is a 38,000-square-foot facility that encompasses clean rooms for thin-film deposition and device processing and conventional laboratories for surface/interface and bulk electrical and optical characterization.

The MDL's facilities, covering all aspects of laser fabrication and testing, have provided the basis for innovative device development programs at JPL. A new semiconductor laser structure capable of providing emission in the 1.6-2.1-micron range has been demonstrated for the first time, using InGaAs/InP strained quantum-well lasers with very low threshold current density and high external quantum efficiency. These lasers will be used for spectroscopic applications and injection-locking solid-state lasers for lidars. DOD- and NASA-sponsored research has led to the creation of pseudomorphic InGaAs/GaAs lasers emitting at 980 nanometers with record-breaking output powers, and an integrated pair of tunable GaAs single-mode lasers for generation of Ka-band signals in miniature spacecraft.

In instrument design, JPL recently produced a compact design for the Pluto Fast Flyby mission, consisting of a visible camera and imaging spectrometers for both the infrared and far-ultraviolet. These are combined in one instrument, saving weight, and resulting in a light instrument suitable for small spacecraft.

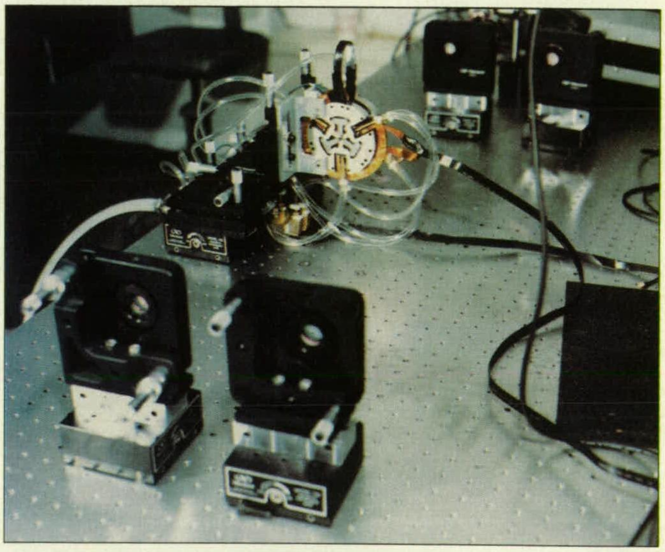
Langley Research Center

Langley Research Center has several programs for laser development and application, including a space shuttle program (LITE), an aircraft program (LASE), and the solid-state eyesafe laser development program.

The first flight of the LITE experiment, to focus on demonstration of the technology, will determine the dynamic range of backscatter from aerosols, clouds, the ground, the sea surface, and molecules in the atmosphere. Atmospheric scientists will obtain, for the first time, fundamental transmission measurements from the top of the atmosphere to the Earth's surface in three laser wavelengths. This data set will be valuable in validating radiative transfer codes from space to the ground.

The LITE palette, a lidar testbed, is guided by an international scientific team. The Laser Transmitter Module (LTM) design consists of redundant three-color flashlamp-pumped Q-switched Nd:YAG lasers, and the optical system employs an oscillator followed by two amplifier stages. A CD*A doubler and KD*P tripler are used to convert the 1.06-micron fundamental frequency to 0.532 and 0.355 microns. The LITE laser has demonstrated 550, 600, and 200 millijoules at these wavelengths, respectively. The LTM is housed in a sealed canister pressured to one atmosphere with dry nitrogen gas. Development of the rest of the LITE experimental hardware and software is on schedule. A series of atmospheric tests in the spring of this year successfully verified end-to-end performance, and LITE is scheduled to fly on the space shuttle in September 1994.

The LASE program, based on a tunable Ti:sapphire laser transmitter, is the first step in the overall NASA effort to develop and demonstrate an autonomous tunable DIAL laser instrument for airborne and spaceborne flight experiments. It also will conduct scientif-

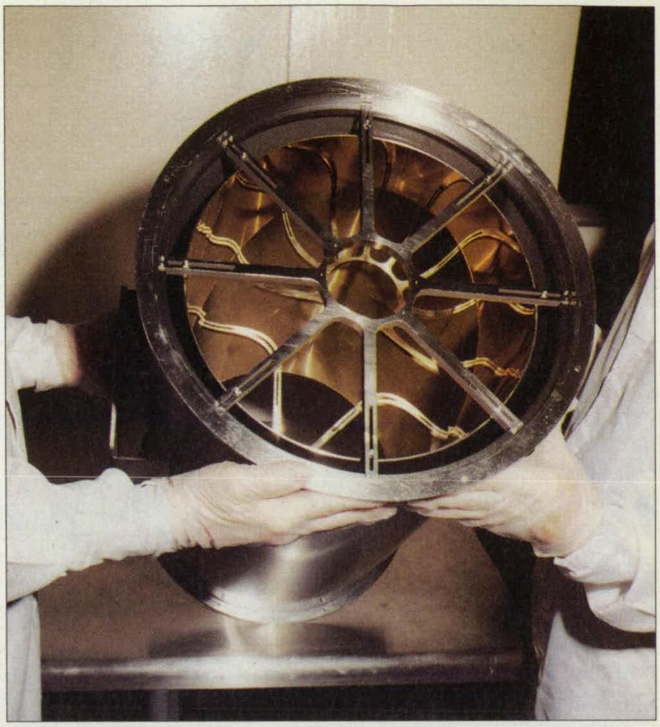


Among the systems developed in Langley Research Center's solid-state laser program is a pulsed diode-pumped ring laser that can perform Doppler wind measurements with 1-meter-per-second accuracy.

ic investigations of tropospheric water vapor and aerosols on a broad spatial scale. The Nd:YAG-pumped Ti:sapphire laser's wavelength is tunable from 813-818 nanometers and is controlled by injection seeding with a tunable diode laser. The laser operates in a double-pulsed mode at 5 hertz with the first pulse on a water-vapor absorption line and the second 400 microseconds later off the line. The LASE instrument is scheduled for flight on the ER-2 aircraft later this year, and an extensive field experiment to validate its measurements will be conducted in early 1994.

The Langley Center's developmental program in eyesafe solid-state lasers includes quantum mechanical modeling of new laser materials, growth, and fabrication of promising materials, spectroscopic evaluation of existing materials; and breadboard demonstration of diode-pumped solid-state systems. The program's goals include the measurement of safety hazards, including wind shear and trailing vortices from aircraft, and the measurement of atmospheric constituents such as water vapor and greenhouse gases.

Results to date have included the identification through a quantum mechanical model of a new 2-micron laser material, Ho:Tm:LuAG; a single-frequency continuous-wave diode-pumped monolithic 2-micron laser; a high-efficiency (5.9% optical-to-optical) Ho:Tm:YLF laser; a 2-micron pumped optical parametric oscillator; and the demonstration of a diode-pumped ring laser with the pulse length required for Doppler wind measurements to accuracies of 1 meter per second.



For the AXAF-S program, Marshall Space Flight Center prototyped a nickel replicated mirror that supplied data on diamond turning and electroplating techniques.

Marshall Space Flight Center

The optics and laser programs of Marshall's Optics and Radio Frequency Division have as their primary goals to advance the state of the art in photonics and to serve as repositories of technology and a focal point for technology transfer between industry, government, and academia.

Among its most important projects is the Advanced X-ray Astrophysics Facility (AXAF). This is a two-part program: AXAF-I focuses on imaging and AXAF-S on spectroscopy. For the AXAF-I sector, Marshall provides technical oversight of the mirror fabrication at Hughes Danbury Optical Systems and of the assembly and alignment at Kodak's Federal Systems Division. In addition, Marshall has done research, development, and testing in the areas of coating, particulate contamination measurement, glass strength, metrology, and performance analysis. For AXAF-S, Marshall is developing a prototype nickel replicated mirror, which involves investigations into diamond turning, polishing, and electroplating.

Marshall maintains a pulsed carbon dioxide lidar testbed capable of operating in a laboratory, semi-trailer, or aircraft. This system has obtained the first real-time wind field maps from an airborne platform. Also utilizing lidar, Marshall undertook a series of tests at the Kennedy Space Center for monitoring launch and landing wind profiles with radar and both carbon dioxide and solid-state lidar. Additionally, the Optical Systems Branch pursues coherent lidar research and development.

The Optics and Radio Frequency Division has some unique facilities to promote its work. The Optical Systems Branch is building a binary optics facility capable of design and fabrication of diffractive/refractive optics. Designers are using industry-standard optical design software to fashion such optical elements. The refractive part is fabricated in the branch's optical shop, where conventional lenses and mirrors are ground and polished. The diffractive counterpart is etched into the refractive substrate through a process that uses in-house microelectronics equipment such as a mask generator, a step-and-repeat system, a high-resolution mask aligner, and an ion milling machine. This binary-optics capability provides for the study of future space-related diffractive/refractive optics applications.

Ongoing projects at Marshall's Electro-Optics Branch include development of a Multi-Center Airborne Coherent Atmospheric Wind Sensor (MACAWS), investigation of coherent Doppler shift for shuttle launch and landing wind profiling, and development of a 2-micron solid-state coherent Doppler lidar system.

As part of NASA's Laser Atmospheric Wind Souder (LAWS) mission, MACAWS will fly an approximately 1-joule, 30-hertz CO_2 coherent Doppler lidar in the NASA DC-8 airplane in 1995 to investigate atmospheric dynamical processes and to explore wind velocity measurement and algorithms. Marshall is designing and upgrading the MACAWS Operation Control System, the Germanium wedge scanner and aircraft windows, and the Inertial Navigation Unit computer and software.

For wind measurement in support of the space shuttle program, Marshall has coordinated two field demonstrations at Kennedy Space Center. A 1991 experiment evaluated a 1-joule CO_2 lidar for shuttle launches; while an experiment this year tested a 915 megahertz radar, a Ho,Tm:YAG coherent lidar, and a CO_2 lidar for shuttle landings. The center currently is analyzing and comparing the lidar and radar data with wind data from rawinsondes and the shuttle flight performance derived winds.

The Solid-State Coherent Doppler Lidar Program will develop wind velocity profiling using solid-state lasers. These lasers potentially offer lower mass, longer life, and no necessary consumables for future remote sensing missions. Marshall is developing facilities, including a test bed, to evaluate lasers, detectors, and calibration targets for solid-state Doppler lidar systems. **LTB**

For more information about the technologies described in this article, contact the technology transfer officer at the field center that sponsored the research *(see page 10).*

Synchronizing a Stroboscope With a Video Camera

The light flashes at a preset delay after each vertical-synchronization pulse.

Langley Research Center, Hampton, Virginia

A circuit synchronizes the flash of light from a stroboscope with the frame and field periods of a video camera. The circuit is designed especially for use in making short-exposure images that "freeze" the flow in a wind tunnel. It can also be used for making longer-exposure images like those that would be obtained by use of continuous intense illumination. Heretofore, two separate lamps and power supplies have typically been needed to produce both pulsed and continuous illumination.

The circuit offers important advantages over circuits that implement other methods of synchronization. For example, synchronization from the ac powerline works well with vidicon cameras and older charge-coupled-device cameras, but modern cameras contain internal clocks that are not locked to the 60-hertz power frequency. Yet another approach, synchronization from an external trigger generator, requires special, more-expensive cameras.

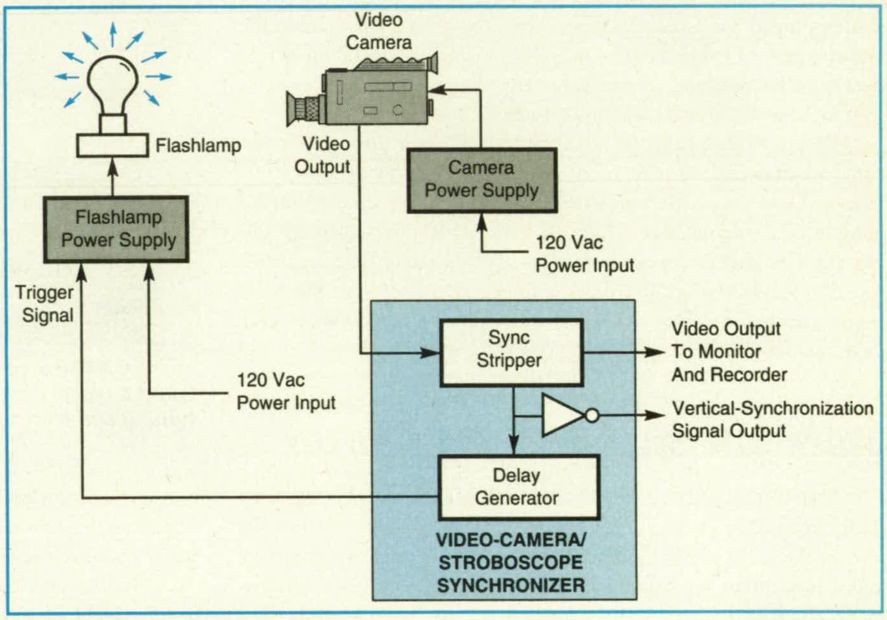


Figure 1. The **Sync Stripper Sends** a vertical-synchronization signal to a delay generator, which generates a trigger signal. The flashlamp power supply accepts the delayed trigger signal and sends a pulse of power to flash the lamp.

The circuit extracts the vertical-synchronization pulses from the output signal of the video camera and uses these pulses to trigger the flashes (see Figure 1). The portion of the circuit that does this is a commercial "sync-stripper" integrated circuit (National Semiconductor LM1881 or equivalent): it processes a standard video signal to produce vertical-synchronization, odd/even-field, and burst-gate/back-porch outputs.

Only a few discrete components are needed in addition to the sync stripper. Switch SW_1 is set open (for high impedance) when this stroboscope-synchronizing circuit is spliced into a video transmission line, but is closed when this circuit is at the end of the line, terminating the line in 75-Ω resistor R_1 (see Figure 2). Capacitor C_1 provides dc isolation, while C_2 filters the dc power to the integrated circuit. The vertical-synchronization pulse is inverted in use; transistor Q_1 converts it to an uninverted pulse for use in troubleshooting and testing.

A CD4098 dual monostable multivibrator integrated circuit generates a delayed pulse after the end of each vertical-synchronization pulse. This delayed pulse is the one that triggers the flashlamp power supply; the delay is necessary in the case of a charge-coupled-device video camera because the CCD output of such a camera is shifted during the vertical blanking interval, and any light during this time would either shift the image vertically on the monitor or create vertical streaks, depending on the duration of the flash. With C_5 and R_5 set at the values shown in Figure 2, the delay is about 2.5 ms. C_6 and R_6 determine the duration of the trigger pulse; for the values shown in Figure 2, the pulse lasts about 1 ms (the flashlamp power supply, not the duration of the trigger pulse, determines the duration of the flash).

The circuit in Figure 2 is designed for use with a single-field-integrating charge-coupled-device camera. If it is used with a two-field integrating camera, two flashes occur during each field, and the even and odd fields are exposed to the same two flashes. To eliminate this effect, the lead to pin 3 of the sync separator should be moved to pin 7 (odd/even output). Once this is done, a trigger pulse occurs only once per frame, after the end of the first field.

This work was done by David B. Rhodes, John M. Franke, Stephen B. Jones, and Harriet R. Dismond of **Langley Research Center**. *Further information may be found in NASA TM107648 (N92-30737), "A Stroboscopic Technique for Using CCD Cameras in Flow Visualization Systems for Continuous Viewing and Stop Action Photography."*

Copies may be purchased (prepayment required) from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650.

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page **10**]. Refer to LAR-14855.*

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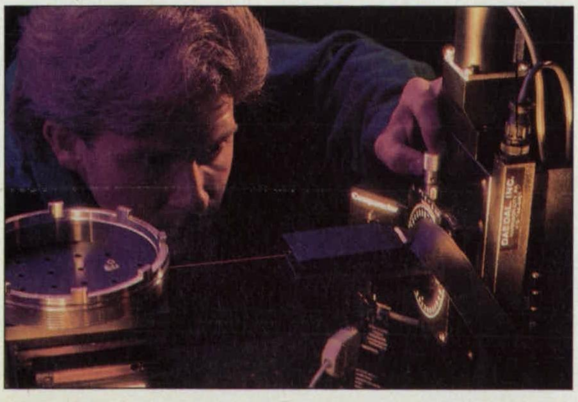

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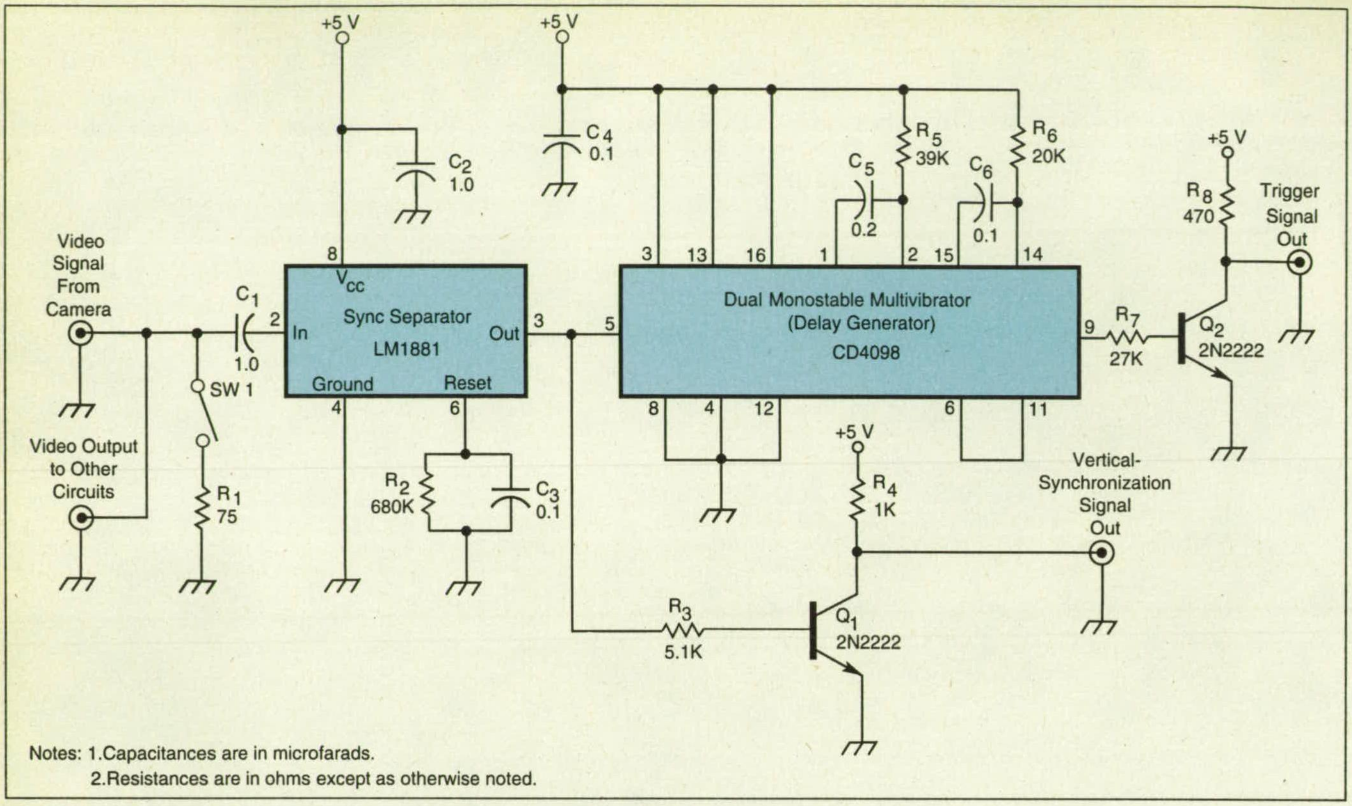


Figure 2. The **Video-Camera/Stroboscope Synchronizer** includes two integrated circuits and a few discrete components. The values of components shown are for standard National Television System Committee (NTSC) video signals. The sync separator operates with power-supply voltages from 5 to 12 V and video inputs from 0.5 to 2 V peak to peak.

Micromachined Electron-Tunneling Infrared Detectors

Pneumatic infrared detectors would be smaller than Golay cells and more sensitive than pyroelectric sensors.

NASA's Jet Propulsion Laboratory, Pasadena, California

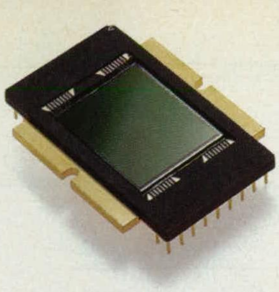
Pneumatic/thermal infrared detectors of a proposed new type would be based partly on the Golay-cell concept, but would be smaller and less fragile than Golay cells are. Like Golay cells, the new detectors would include containers filled with air or other gas trapped behind diaphragms. Infrared radiation would heat the sensors, causing the gas to expand. In Golay cells, the resulting deflections of the diaphragms are measured optically, but in the new detectors, the deflections would be measured by displacement sensors based on the principle of the electron-tunneling transducers of scanning tunneling microscopes.

The miniaturization and enhancement in performance of the new detectors are made possible by two notable technological advancements. Of course, one of them is the development of the electron-tunneling transducers, which are the most sensitive of all compact displacement transducers. The other enabling advancement is the emergence of micromachining of silicon. The mechanical components of the detectors could be made by micron-scale photolithography, which should also enable the fabrication of planar arrays of detectors for use in imaging. The use of tunneling and micromachining allows the miniaturization of the Golay cell without loss of sensitivity.

The figure shows a representative detector of the new type, which occupies an area of about 4 cm^2 and is made from three wafers of silicon 200 μm thick. To make the diaphragm, a layer of stress-free silicon oxynitride is formed by chemical-vapor deposition on the front surface of one of the wafers. To form the container for the gas, a pyramidal cavity with a base of about 1 mm^2 would be etched through this wafer from the back side toward the front, stopping at the inner surface of the diaphragm. This first wafer would be placed diaphragm side up on the second wafer, trapping the air or other gas in the etched cavity. A conductive layer to serve as a counterelectrode to the tunneling tip would be deposited on the top of the diaphragm. The tunneling tip, which would be shaped like a pyramid, would be fabricated from the third silicon wafer by recently developed photolithographic and etching techniques.

Once all the parts were assembled, a bias voltage would be applied to electrostatic-deflection electrodes, which would control the small (of the order of angstroms) separation between the tunneling tip and the counterelectrode upper surface of the diaphragm. This separation would be regulated by feedback control of the electron-tunneling current between the tip and the counterelectrode, as in a scanning tunneling microscope. Upon absorption of IR radiation, the expansion of the gas deflects the membrane. The tunneling transducer converts this deflection to an electrical signal.

Theoretical calculations of response and noise indicate that the new detectors should exeed the sensitivity of all



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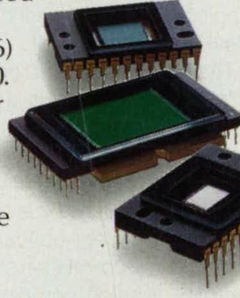

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other miniature, uncooled infrared sensors presently available. Other desirable characteristics of the new sensors are expected to include low consumption of power, broadband sensitivity, room-temperature operation, and invulnerability to ionizing radiation.

This work was done by Thomas W. Kenny, William J. Kaiser, and Stephen B. Waltman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 77*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

William T. Callaghan, Manager
Technology Commercialization
Jet Propulsion Laboratory
(M/S 301-350)
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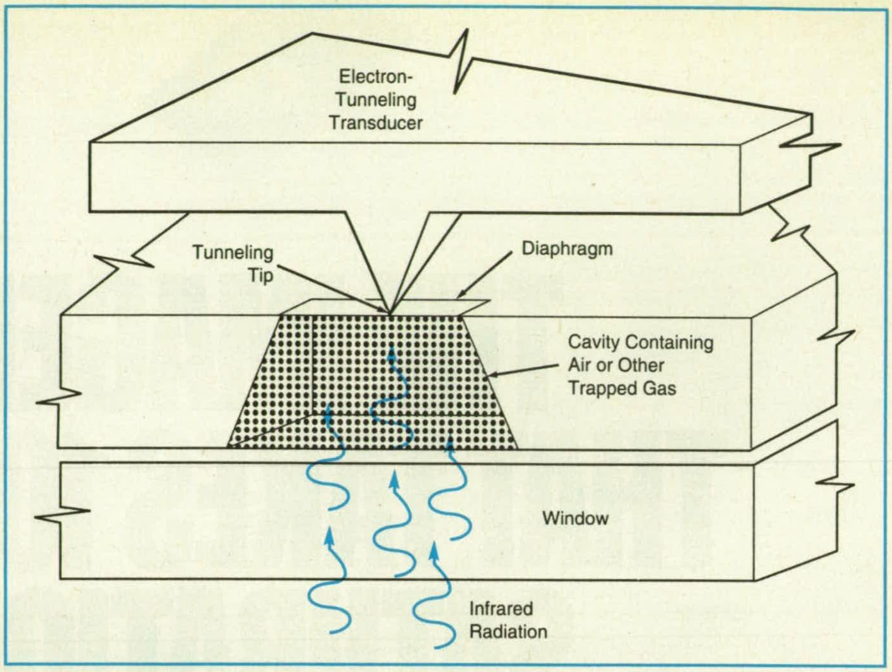


A **Microscopic Cell** containing air trapped behind a diaphragm would be made mostly of silicon, by use of techniques of photolithography and chemical etching. An electron-tunneling transducer with a tunneling tip also made by photolithography would measure the displacement of the diaphragm when the cell was heated by infrared radiation.

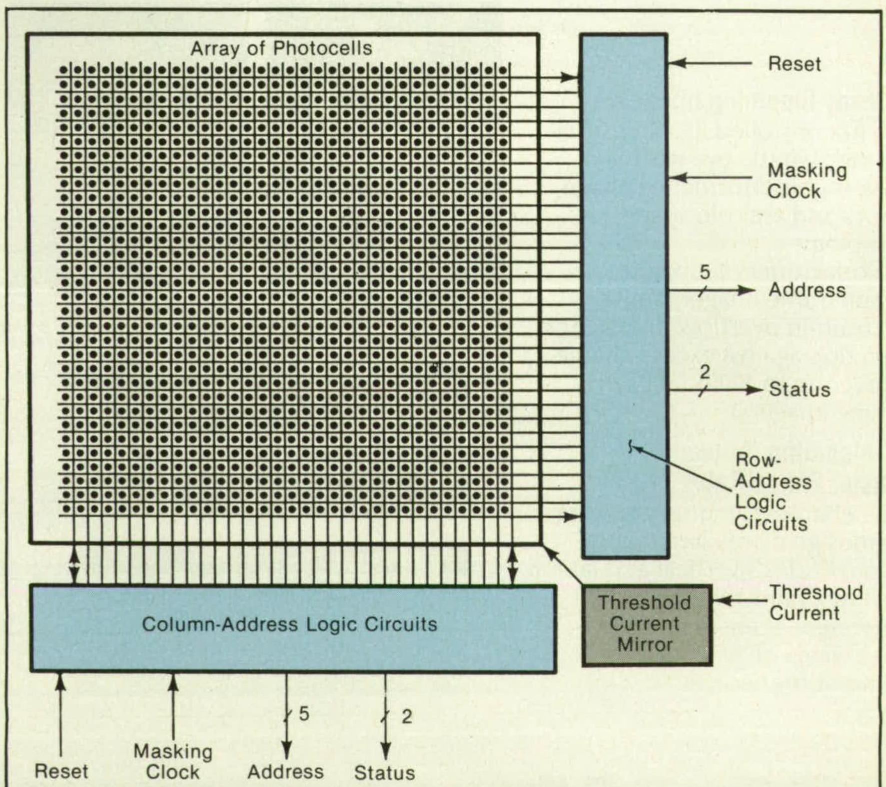
Photodetector Array for Neural Network

This integrated circuit performs 1,024 threshold operations in parallel.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure is a simplified schematic diagram of an improved 32 × 32 integrated-circuit array of photodetectors and associated processing circuitry. This integrated circuit is designed especially for use in postprocessing the output of an optical correlator in an optoelectronic neural network. The overall function of this device is to put out digital signals indicative of the location(s) of the bright spot(s) on the detector plane (which is placed at the correlation plane): these bright spots represent the correlation peaks. The response time of this device is 10 ms in the worst case — much less than that of a typical commercial charge-coupled-device (CCD) imaging detector operating at the standard television frame rate.

The photodetector in each cell or pixel of the 32 × 32 array is a quasi-parasitic bipolar npn phototransistor. Unlike a CCD array, this device provides for simultaneous thresholding of the outputs of all the photodetectors: thresholding is necessary for rejection of ambient optical noise and undesired cross-correlation signals. Each cell contains a small complementary metal oxide/semiconductor (CMOS) transistor circuit that performs the threshold operation by comparing the phototransistor current with an externally adjustable current representative of the threshold illumination level. The thresholding circuitry operates



This **Integrated-Circuit Photodetector Array** includes analog and digital circuits that, acting together, indicate sequentially the addresses of any and all pixels illuminated above an adjustable threshold brightness.

over a dynamic range of about 2 orders of magnitude, with a ±10-percent tolerance on the threshold.

The location of each cell in which the illumination exceeds the threshold (but not the intensity of illumination at that location) is encoded and fed to output terminals via digital logic circuitry that is part of the integrated circuit and that is adjacent to the 32 × 32 detector-array area. When a bright spot hits a pixel, the logic circuitry responds by generating the 5-bit row address and the 5-bit column address of the affected pixel. After determining the address of a bright spot, the circuit generates an internal command to determine whether there is another bright spot, and, if so, its location. This process is repeated so that digital signals indicative of the locations of any and all bright spots are generated in sequence.

Each iteration of this process takes about 1 μs; that is, it takes only about 1 μs to report the address of each pixel in which the brightness is above threshold. Thus, even in the unlikely event that all pixels are illuminated above threshold, it still takes only about 1 ms to report all addresses. The main limitation on the speed of response of the overall circuit is imposed by the photodetector and threshold circuitry, the response time of which depends on the selected threshold level and on the power-supply voltage of the associated digital circuitry. The response time of the overall circuit varies from 1 ms to the maximum of 10 ms mentioned previously.

This work was done by Harry Langenbacher, Tien-Hsin Chao, Timothy J. Shaw, and Jeffrey Yu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 50*** *on the TSP Request Card. NPO-18636*

Fiber-Optic Discriminator Stabilizes Microwave Oscillator

Phase and frequency are stabilized by use of an improved delay-line frequency discriminator.

NASA's Jet Propulsion Laboratory, Pasadena, California

Figure 1 illustrates a microwave oscillator circuit in which both long-term and short-term fluctuations in the phase and frequency of the output signal are reduced substantially. In essence, the scheme for stabilization of phase and frequency relies on negative phase- or frequency-feedback derived from a wideband microwave frequency discriminator based on a fiber-optic delay line.

In the past, frequency discriminators based on delay lines have been among the devices used to stabilize the output frequencies of oscillators operating at lower frequencies. However, to achieve stable operation at microwave frequencies at 10 GHz and above previously required frequency-multiplication electronics, which multiplied phase errors and added complexity. Optical fiber has very high inherent bandwidth, and recent advances in the frequency response of lasers, electro-optic modulators, and photodiodes now make possible long analog microwave delay lines with extremely high stability to frequencies in excess of 20 GHz. Thus, the new fiber-optic delay line discriminator enables stabilization of oscillators directly at the microwave output frequency, eliminating the need for frequency multiplication. Also, the discriminator is a wide-band device, capable of stabilizing the outputs of frequency-agile microwave sources over multigigahertz tuning ranges.

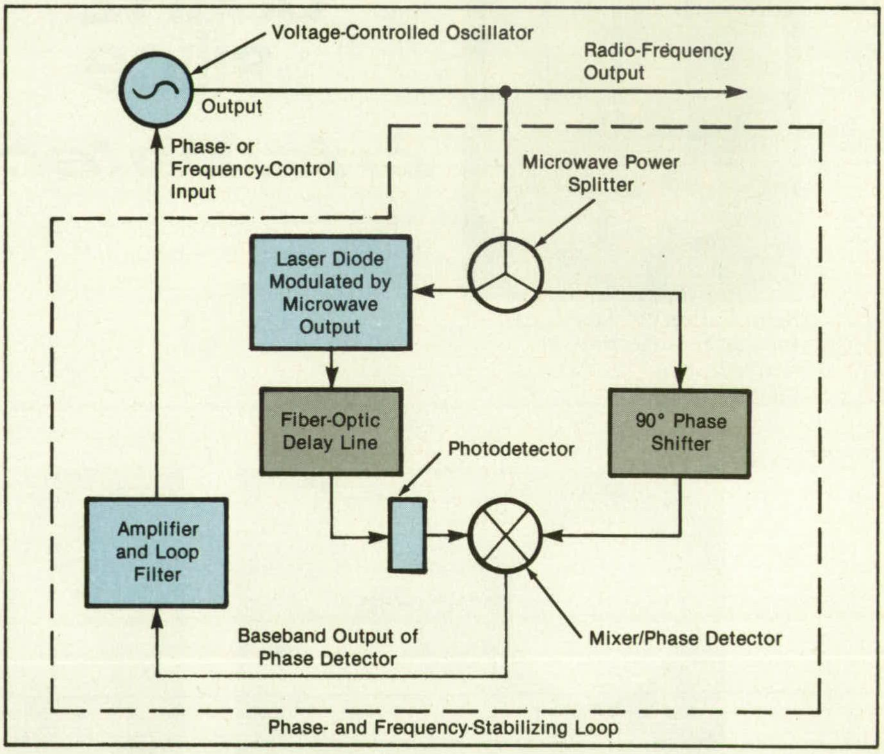


Figure 1. **Negative Phase- or Frequency-Fluctuation Feedback** stabilizes a microwave oscillator.

In the experimental apparatus depicted in Figure 1, the phase or frequency of the oscillator (VCO) can be varied via a control voltage. Part of the microwave output of the oscillator is directed into the frequency discriminator, in which a sample of the microwave signal is used to modulate a laser beam at the input of the fiber-optic delay line. The output of the fiber-optic cable is detected with a fast photodiode, and compared in phase quadrature (90° offset) with the undelayed signal using a mixer operated as a phase detector. The output of the mixer/phase detector is a baseband fluctuation in voltage approximately proportional to the fluctuations in the frequency of the VCO. These baseband fluctuations are amplified, filtered, inverted, and applied as negative feedback to the control-voltage input terminal. An analysis predicts that the fluctuations of the oscillator can be reduced to a level limited by the $1/f$ phase noise of the delay components.

In a preliminary experiment, a 7.8 GHz cavity-tuned signal generator VCO was operated with and without a frequency-stabilization loop. The loop included a discriminator containing an optical fiber 6.2 km long, (31 μs of delay), an injection-modulated Fabry–Perot semiconductor laser diode at the input end and a photodiode receiver at the output end, a microwave phase shifter to achieve 90° phase quadrature at the inputs of a double-balanced mixer/phase detector, and a single-pole inverting loop filter. Figure 2 shows that the loop produced a 45 dB reduction in the phase noise of

the oscillator, in excellent agreement with the theoretical prediction. The use of advanced fiber-optic delay line with wider bandwidth and low noise are predicted to yield corresponding improvements in phase-noise performance. The widely tunable fiber-optic stabilized oscillator is therefore comparable in phase-noise performance to present surface-acoustic-wave (SAW) and dielectric resonator oscillators (DRO's), both of which have severely limited tuning capabilities.

This work was done by Ronald T. Logan, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 2*** *on the TSP Request Card.*

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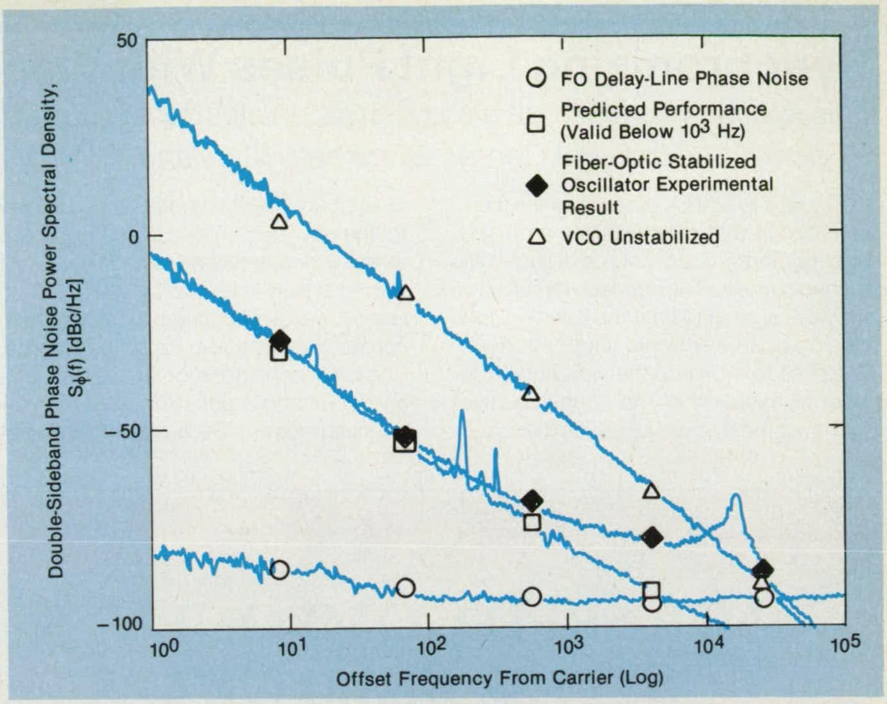


Figure 2. The **Measured Phase Noise of an Oscillator**, expressed as a relative power spectral density, was clearly reduced by a stabilizing loop, at offsets up to 10^4 Hz.

Synchronizing Light Pulses With Video Camera

This synchronizing circuit also controls an electronic shutter.

Goddard Space Flight Center, Greenbelt, Maryland

Figure 1 is a block diagram of an interface circuit that synchronizes a pulsed laser or other pulsed source of light with a video camera. The interface circuit also provides signals to time the opening and closing of an electronic shutter in such a way as to enhance the visibility of the laser illumination in the scene relative to that of the background illumination.

Synchronization is desirable not only for the obvious purpose of ensuring consistency for measurement and control but also to ensure the visibility of the pulsed laser illumination during playback of a recorded video image in the "pause" mode. The latter consideration arises because a video image is constructed in two sequential fields and because a typical commercial video cassette recorder operating in the "pause" mode displays only the first or else the second field (which one depends on the particular model) of the video frame selected for still viewing. Thus, if the laser is allowed to flash at random times during recording, then about half of all pulses are likely to occur during the field that is not displayed in the "pause" mode. Thus, the field that is displayed in the "pause" mode may not contain the pulsed laser illumination.

This interface circuit includes a commercial sync-stripper integrated circuit, which derives frame-synchronization pulses from the video signal produced by the camera. The interface circuit can operate in either of two modes: "automatic" or "external." In the "automatic" mode, it generates laser-trigger pulses at intervals of a preset number of frames and at a specified instant within the proper field for viewing during playback in the "pause" mode (see Figure 2). The instant of triggering within the proper field is established by use of an adjustable-delay multivibrator. The number of frames between laser pulses is controlled by a counter and comparators: the counter repeatedly counts up to that number, which is preset by use of a dual-in-line-package (DIP) switch that is accessible to the technician and is connected to one of the inputs of one of the comparators.

For a video camera that includes an externally controllable electronic shutter, the interface circuit also generates control signals that essentially increase the shutter speed during an interval that includes the frame in which the laser is triggered. At a preset (also by use of a DIP switch) number of frames before the laser is to be triggered, the interface circuit begins to put out the fast-shutter toggle signal, which overrides the normal "slow" shutter-control signal and causes the shutter to be opened during a shorter interval that includes the laser pulse. Thus, the contribution of background illumination to the video signal is reduced relative to that of the laser illumination during the frames that contain the laser pulses. After a preset total-shutter-stopdown time, the shutter is allowed to return to its normal operation.

When operating in the "external" mode, the interface circuit does not repeatedly produce laser-trigger pulses at regular intervals. Instead, it produces one laser-trigger pulse in response to each trigger pulse supplied from an external source.

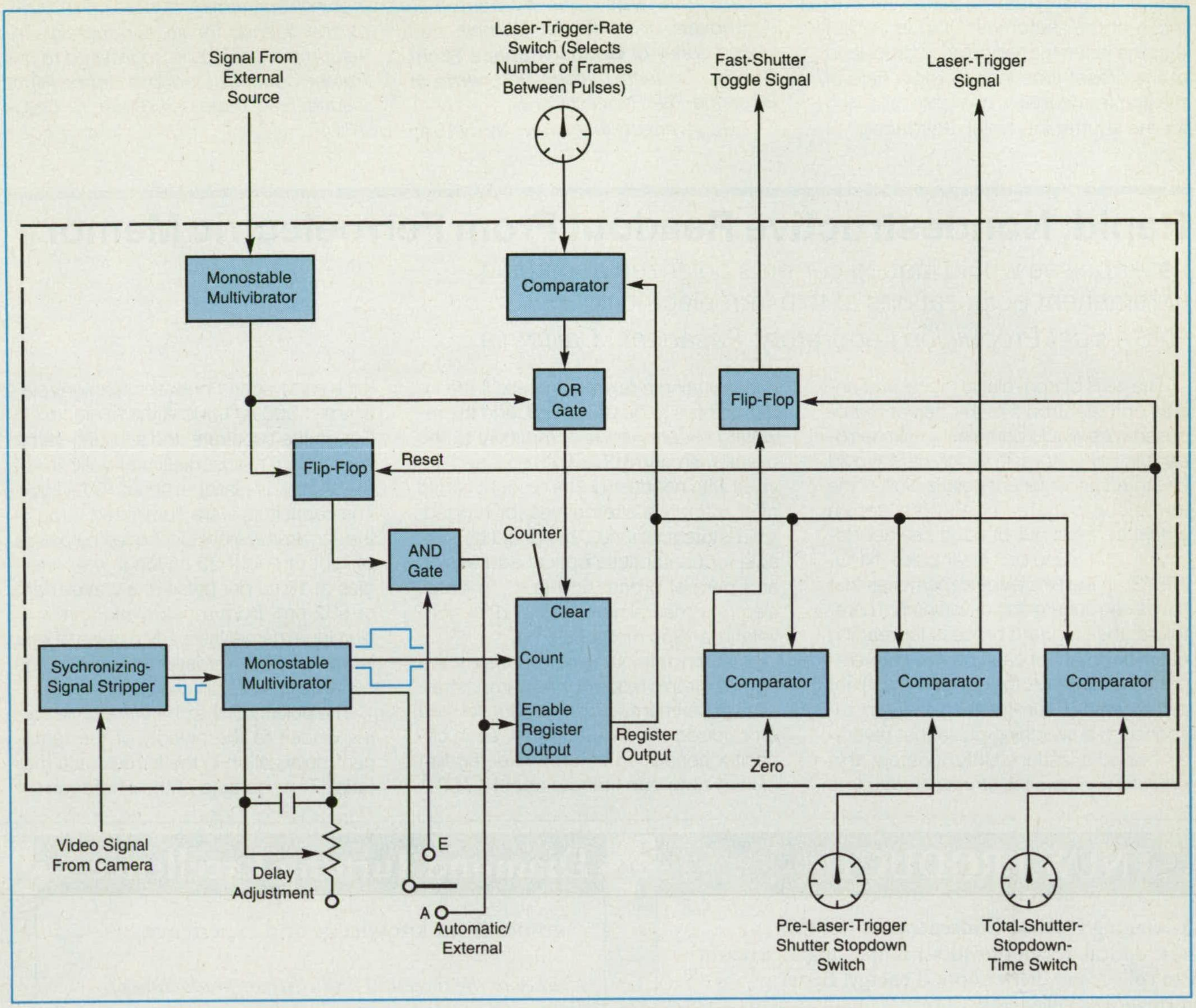


Figure 1. This **Interface Circuit** triggers a laser or other external source of light to flash in the proper frame and field (at the proper time) for video recording and playback in the "pause" mode. It also increases the speed of the electronic shutter (if any) during the affected frame to reduce the visibility of background illumination relative to that of the laser illumination.

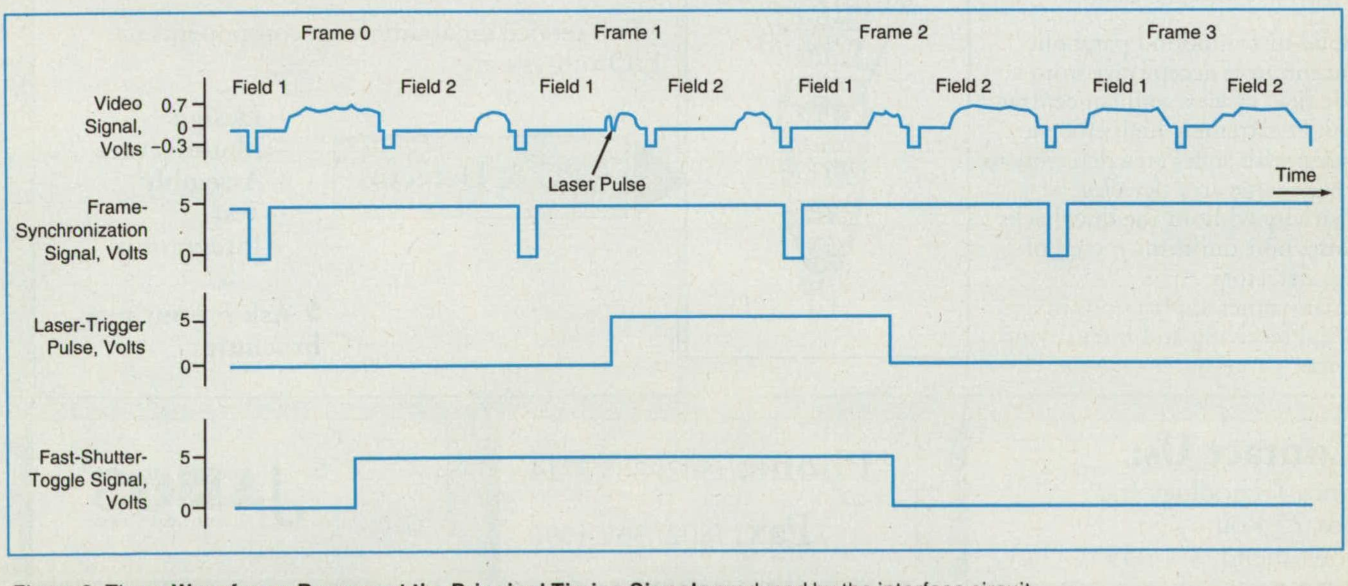


Figure 2. These **Waveforms Represent the Principal Timing Signals** produced by the interface circuit.

The synchronizing, adjustable-delay, and shutter-opening functions are similar to those of the "automatic" mode except that the laser-trigger pulse is produced at the preset time in the proper field of the first frame that is available (allowing for the shutter intervals) after receipt of the external trigger pulse.

This work was done by James E. Kalshoven, Jr., Michael Tierney, and Philip Dabney of **Goddard Space Flight Center**. *For further information,* ***write in 20*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page ***10****]. Refer to GSC-13546.*

Rapid, Nondestructive Readout From Ferroelectric Memory

Laser pulses would induce currents polarized according to remanent polarizations of thin ferroelectric films.

NASA's Jet Propulsion Laboratory, Pasadena, California

The cells of nonvolatile digital and analog optoelectronic memories of a proposed type would contain thin-film ferroelectric capacitors, in which data would be stored as remanent polarization of the ferroelectric material, and the datum would be read out of each cell nondestructively by use of a laser pulse (NPO-18573). In the ferroelectric memories that have been undergoing development heretofore, the standard process for reading out the content of each capacitor/memory cell has been to read the transient displacement current that flows in response to a switching pulse that reverses the polarization. Unfortunately, this process destroys the stored information, necessitating a rewrite process if the information is to be preserved, and the rewriting circuitry adds complexity to the overall memory circuit. The proposed devices with nondestructive readout would offer attractive alternatives for rugged, solid-state memories that could be suitable for contactless optical addressing and parallel processing (e.g., in optoelectronic neural networks) and for nonvolatile analog memories.

The principle of rapid, nondestructive optoelectronic readout was demonstrated in experiments on capacitors, formed on oxidized silicon substrates, each capacitor consisting of a ferroelectric film of lead zirconate titanate about 1,700 Å thick sandwiched between titanium/platinum (1,000 Å/1,000 Å thick) electrode film on the substrate and an outer semitransparent electrode film of gold about 300 Å thick or platinum about 100 Å thick. The capacitors were illuminated through the semitransparent electrodes by pulses of light of about 25 ns long, with energies of 10 μJ per pulse at a wavelength of 532 nm, from a neodymium:yttrium aluminum garnet laser. Each pulse of light induced a photoresponse across the capacitor lead as shown in the figure.

The polarity of the photoresponse corresponded to the polarity of the remanent polarization in the ferroelectric material. The rise time of the photocurrent

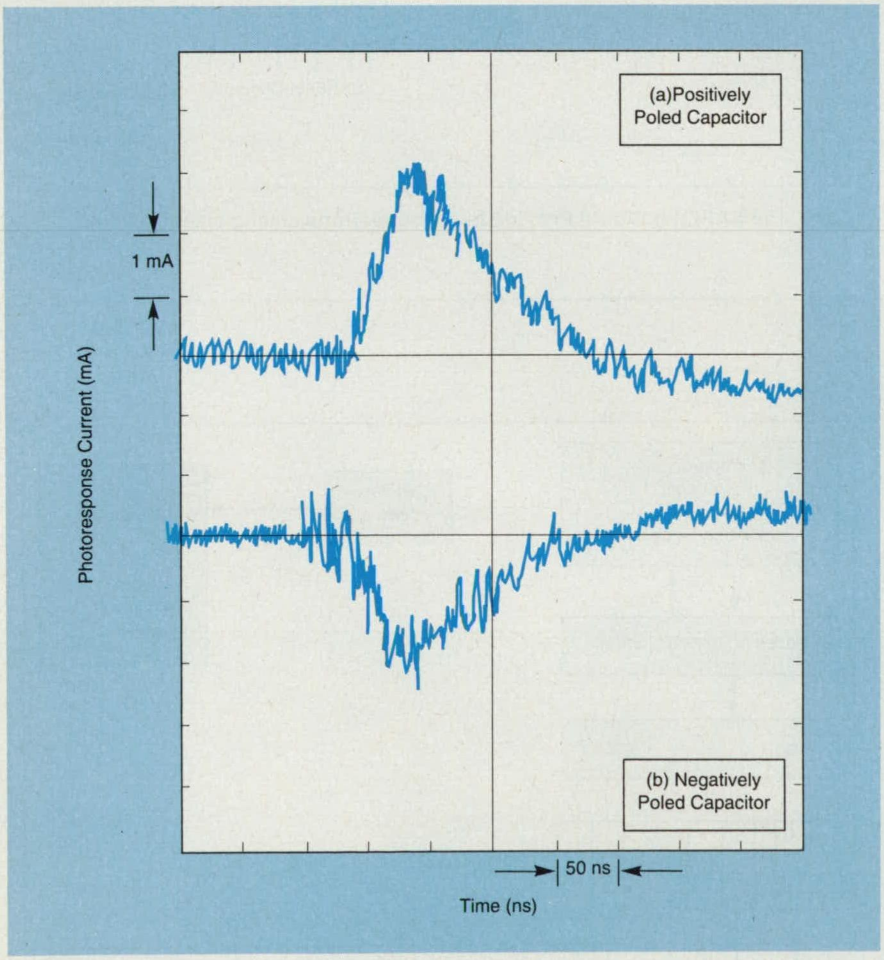
response was about the same as that of the laser pulse, and the decay time was a fraction of a microsecond. The photocurrent responses remained essentially unchanged even after more than 10^6 readout pulses.

It has been hypothesized that the photoresponse might be caused by either or both of two classes of physical mechanisms: (1) photoelectric generation of charge carriers as in the photovoltaic effect, photoconductive effect, localized electronic transitions, or transient space-charge currents or (2) effects caused by heating; e.g., the pyroelectric effect (associated with a change in temperature) or the piezoelectric effect (associated with the propagation of an acoustic wave through the ferroelectric film). A comparison of the photoresponse from capacitors with semitransparent and opaque top electrodes suggests that the observed nondestructive readout signal is primarily due to thermally triggered mechanisms.

In a related investigation, two manufacturing treatments were found to enhance both the proposed optoelectronic-readout ferroelectric memories and the existing polarization-reversal-readout ferroelectric memories. These treatments reduce or eliminate the effects of space-charge and time dependent polarization/depolarization that give rise to instabilities in the operations of the memories. One of these treatments is a voltage-cycling treatment that helps formation of the interfaces. The other treatment is an anneal that is performed after deposition of the semitransparent top electrodes. This treatment reduces the traps and hence the space charge effects and increases the dielectric breakdown strength of the ferroelectric material. It also reduces substantially the change associated with the nonswitching pulse, thereby enhancing the retention as well as fatigue characterisics.

This work was done by Sarita Thakoor of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 58*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL [see page 10]. Refer to NPO-18551.



Pulses of Light from lasers would induce photoresponses in the ferroelectric capacitors. The magnitude and polarity of the response of each capacitor would indicate the magnitude and polarity of its remanent polarization which, in turn, would represent the datum stored in that memory cell.

Scalable Optical-Fiber Communication Networks

Networks for communication among computers could be made simple or complicated as needed.

NASA's Jet Propulsion Laboratory, Pasadena, California

The scalable arbitrary fiber extension network (SAFEnet) is a conceptual fiber-optic communication network that would pass digital signals among a variety of computers and input/output devices at rates from 200 Mb/s to more than 100 Gb/s. The SAFEnet is intended especially for use with very-high-speed (e.g., hypercube) computers and other data-processing and communication systems in which message-passing delays must be kept short. The inherent flexibility of the SAFEnet would make it possible to match the performance of the network to that of the computers by optimizing the configuration of the interconnections. In addition, the SAFEnet interconnections could be made redundant to provide tolerance to faults.

The nodes of the SAFEnet could serve as interfaces between the SAFEnet and other standard optical-fiber or electronic digital communication networks (see Figure 1). Thus, the SAFEnet can be regarded as an extension of such other network(s) — in a sense, as an optical-fiber data-transmission analog of an electric-power extension cord.

The links in the SAFEnet would be cables of optical fibers, called "fat fiber tunnels," in which data could be transmitted in parallel streams on the individual fibers. A serial stream of data coming from a source at a rate too high for one fiber could be demultiplexed into parallel streams for transmission on multiple fibers. The maximum data rate of the network would be that achievable by full parallel transmission on all the fibers in a fat fiber tunnel; this rate could be apportioned as needed by providing the number of parallel fibers required to support the current data rate in each communication channel that is active in the fat fiber tunnel. In other words, the fat fiber tunnel could support one fast channel or multiple slow channels.

Each SAFEnet node (see Figure 2) would be a multiport module, which would consist of a microprocessor-controlled crossbar switch and one or more nodes of a standard electronic or optical-fiber

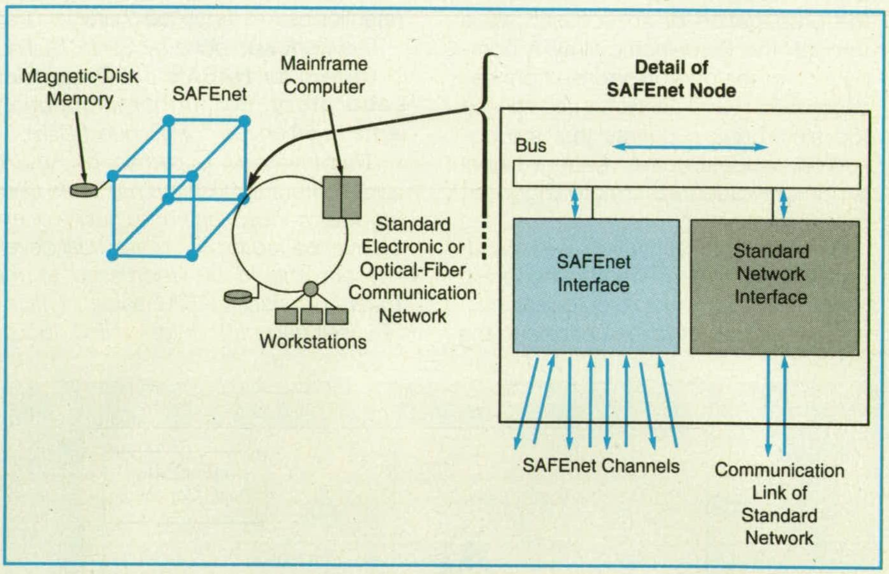


Figure 1. The **SAFEnet Would Provide Interconnections** among other networks.

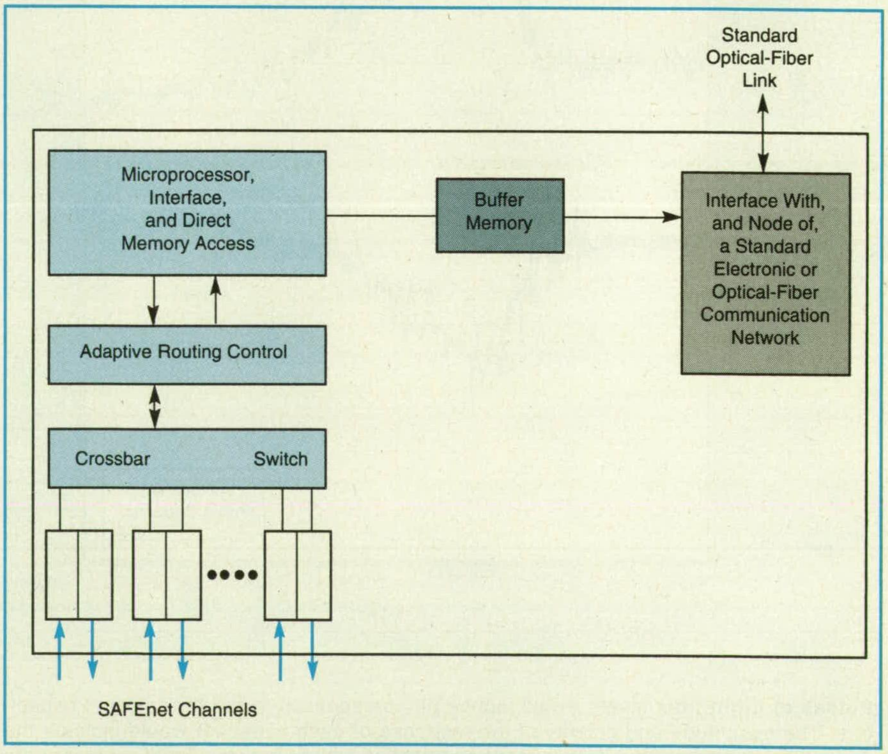


Figure 2. A **SAFEnet Node** would serve as an interface between the SAFEnet and one or more other networks, providing buffering and adaptive routing functions.

communication network(s). Data would flow between the SAFEnet and the standard network through a buffer memory. The crossbar switch would provide adaptive routing control, including the serial/parallel reconfigurations needed to allocate the total available data rate among the faster and slower channels.

This work was done by Edward T. Chow and John C. Peterson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 6*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

William T. Callaghan, Manager
Technology Commercialization
Jet Propulsion Laboratory
(M/S 301-350)
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-18202, volume and number of this NASA Tech Briefs *issue, and the page number.*

Two Modules of a Fly-by-Light System

The system would include fault-tolerant fiber-optic data paths.

Langley Research Center, Hampton, Virginia

A proposed fly-by-light/power-by-wire control system for a commercial aircraft would be designed on the basis of fault-tolerant transmission of digital control data along fiber-optic paths. Important novel features of the system would be embodied in two modules: a redundancy-management unit (RMU) and a fiber-optic serial backplane (FOSB). The RMU would lie in the data path of the FOSB and would perform the fault-tolerance functions. It would isolate faults and provide reconfiguration (in response to faults) of inputs and outputs at the module level, thereby increasing survivability while keeping fault-tolerance overhead at a minimum. The FOSB would be a high-speed time-division-multiplex data bus with fiber-optic transmission, that would be used to interconnect other modules.

The RMU would execute a data-consistency algorithm to protect against Byzantine failures in data processors: a Byzantine failure is one that could cause the remaining properly functioning processors to interpret the same data differently. The design of the RMU would integrate the data-consistency algorithm into its data-transfer protocol

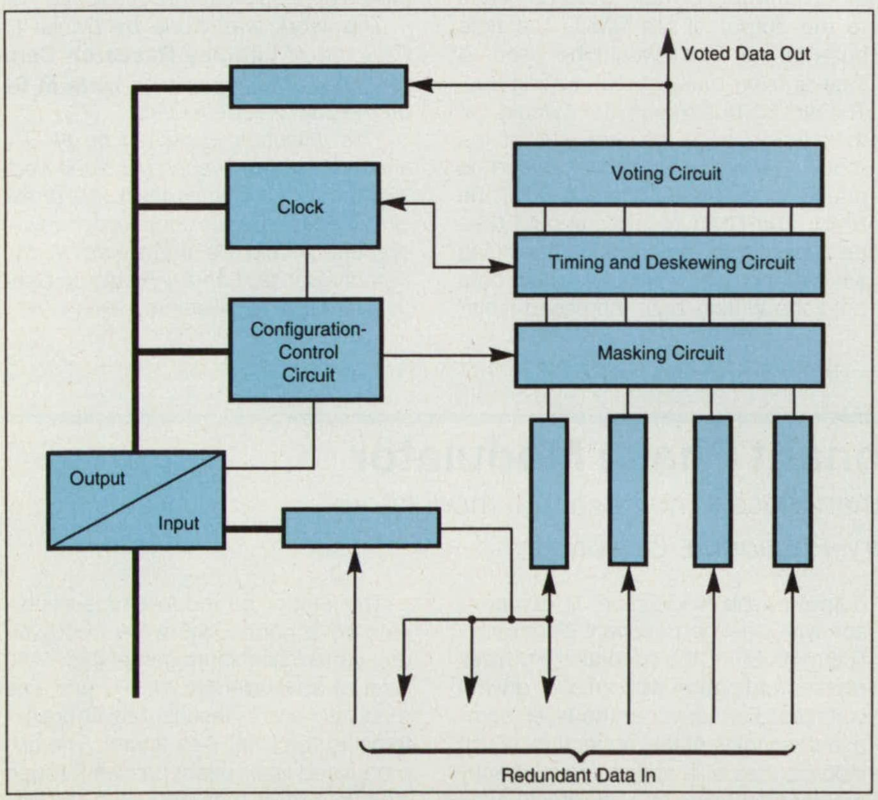


Figure 1. The **Redundancy-Management Unit** would perform the fault-tolerance functions.

to ensure the integrity of critical data and to isolate the possibly harmful behaviors of noncritical components.

The fault-tolerance functions would involve majority voting of redundant input data; this would necessitate synchronization of the data. However, data destined for a voting circuit would originate at different redundant sites at slightly different times. The skew between the slowest and fastest data streams would be bounded by a clock-synchronization algorithm. The data streams would be delayed first by the communication path, and then would have to be delayed further at the voting circuit to deskew them before the vote. Therefore, the voting circuit would have to wait the maximum transmission time plus the maximum expected clock skew before voting the data. To reduce the overhead required for deskewing, the RMU would be designed around block-structured/message-based transmission on the FOSB and other data buses.

Tight synchronization would reduce voting overhead. A local clock would be maintained in the RMU. The RMU would execute the clock-synchronization algorithm, which would guarantee that all local clocks would operate within a defined maximum skew of each other. This would establish a global time base on the system. The global time base would be used to order events on the system, thereby increasing efficiency and enabling validation of the system.

The RMU (see Figure 1) would include serial or parallel input/output ports. The input data would be buffered locally and transmitted to three other RMU's. Any of four data streams could be masked. Data on the time skews among the data streams would be gathered during the synchronization process and used to maintain synchronism with other data channels. The synchronized data streams would be fed to the voting circuit. The voted data would then be available as serial or parallel output.

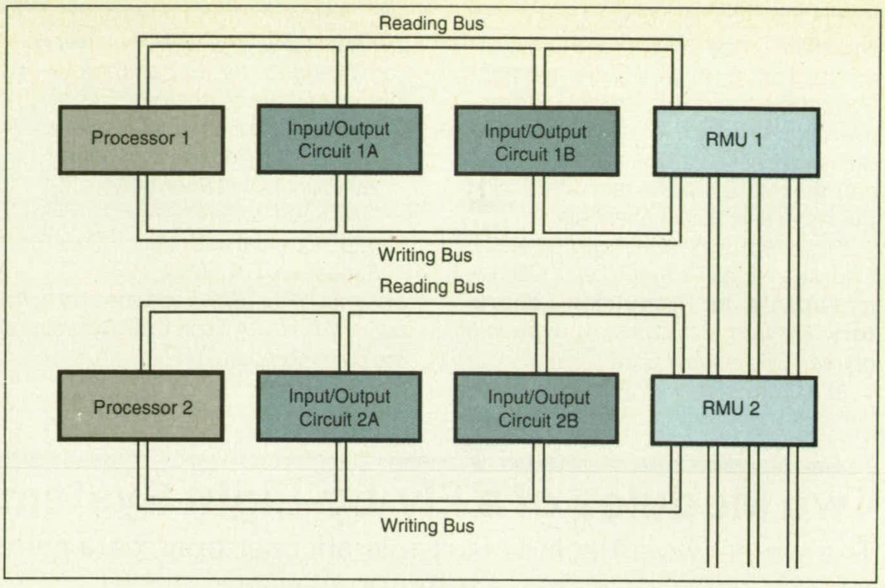


Figure 2. The **Fiber-Optic Serial Backplane** would be a high-speed fault-tolerant time-division-multiplex data bus with fiber-optic transmission.

The FOSB (see Figure 2) would include a reading bus and a writing bus. The output from each module would be placed on the writing bus, where it would be collected and voted by the RMU. Voted data would then be transmitted by the RMU over the reading bus. The reading bus would be a multidrop bus, to which the RMU would have sole writing access. Thus, all modules would be able to lock in phase to the output of the RMU. The time base in the RMU would be used to time-division-multiplex the writing bus. The writing-bus transmitters would get their timing from the receivers of the module, which would be locked in phase to the transmitter clock of the RMU. The RMU receiver should then be subject to minimal shift in the timing as the modules multiplex their data onto the writing bus. Increased isolation of faults on the writing bus could be achieved by use of a transmitter of different wavelength for each module and a broadband receiver in the RMU.

The RMU would establish a fault-containment region at the boundary of the writing bus. The FOSB and RMU would work together to give working processors access to input/output resources on channels with failed processors. For example, in Figure 2, if the processor 1 were to fail, then its input/output resources 1A and 1B would still be accessible to processor 2.

This work was done by Daniel L. Palumbo of **Langley Research Center**. *For further information,* ***write in 64*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquires concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 10]. Refer to LAR-14785.

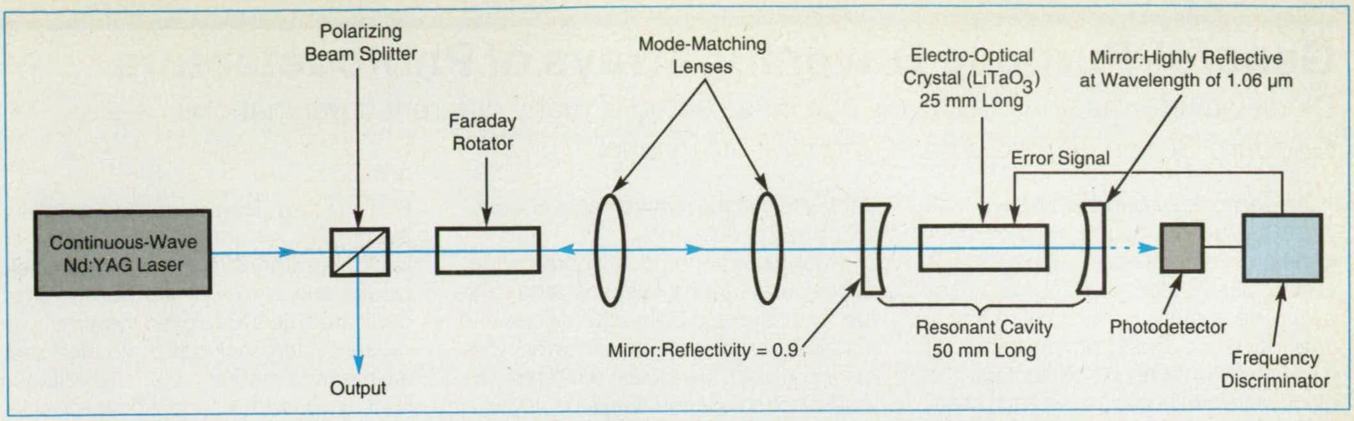
Electro-Optical Resonant Phase Modulator

Driving voltages can be smaller than those of nonresonant modulators.

NASA's Jet Propulsion Laboratory, Pasadena, California

An electro-optical phase modulator that includes an electro-optical crystal in a resonant cavity is suitable for use in transmitting digital data on a laser beam at a data rate of 10 MHz. Switching voltages are applied to the crystal, thereby switching the cavity onto and off resonance, and the large phase dispersion that occurs near resonance provides the output phase modulation. In comparison with older nonresonant electro-optical modulators, this apparatus produces phase modulation with smaller driving voltages. Furthermore, the laser-damage thresholds of this apparatus, which incorporates bulk optics, are inherently greater than those of modulators based on integrated (that is, microscopic) optics.

The light to be modulated is generated by a continuous-wave neodymium: yttrium aluminum garnet (Nd:YAG) laser at a wavelength of 1.06 μm. The modulator and its resonant cavity are external to the laser (see figure). The unmodulated laser beam passes through a beam splitter, then through a Faraday rotator, and is coupled into the reso-



The **Phase of the Beam Reflected From the Resonant Cavity** deviates sharply with deviation of the resonant frequency of the cavity from the laser frequency. This large phase dispersion is exploited to produce phase modulation.

nant cavity by a pair of mode-matching lenses. The output (modulated) beam reflected from the resonant cavity is collinear with the input (unmodulated) beam. The input and output beams are separated by the beam splitter acting in conjunction with a Faraday rotator.

A feedback loop maintains the cavity near resonance at the laser frequency: A frequency discriminator in the loop senses the residual amplitude of the output of the cavity and thereby infers the error between the resonant frequency of the cavity and the laser frequency. The error signal is fed back as a slowly varying, nonmodulation component of the total voltage applied to the electro-optical crystal to drive the resonant frequency of the cavity back toward the laser frequency.

The design of the modulator involves compromises among the rise time of the phase shift, the driving voltage, and the dimensions, reflectivities, and other parameters of the resonant cavity. In calculations and experiments, it was found that typical designs yield phase shifts as large as 90° with driving voltages of ≤5 V. Other calculations have shown that by suitable choices of all the design parameters, it should be possible to reduce the rise time to 4 ns, thereby increasing the data rate from the present 10 Mb/s to 100 Mb/s.

This work was done by Chien-Chung Chen, Deborah L. Robinson, and Hamid Hemmati of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 31*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL [see page 10]. Refer to NPO-18702.

General-Purpose Driver for Arrays of Photodetectors

Clock waveforms and bias levels can be selected in many different combinations.

Goddard Space Flight Center, Greenbelt, Maryland

An electronic system that contains both digital and analog circuits supplies clock waveforms at frequencies up to 12 MHz and/or bias voltages in 16 output channels. The system is designed to provide low-noise driving signals for any of a variety of arrays of photodetectors. The clock waveform and/or bias in each channel can be adjusted independently of the others to suit the requirements of a specific array of detectors.

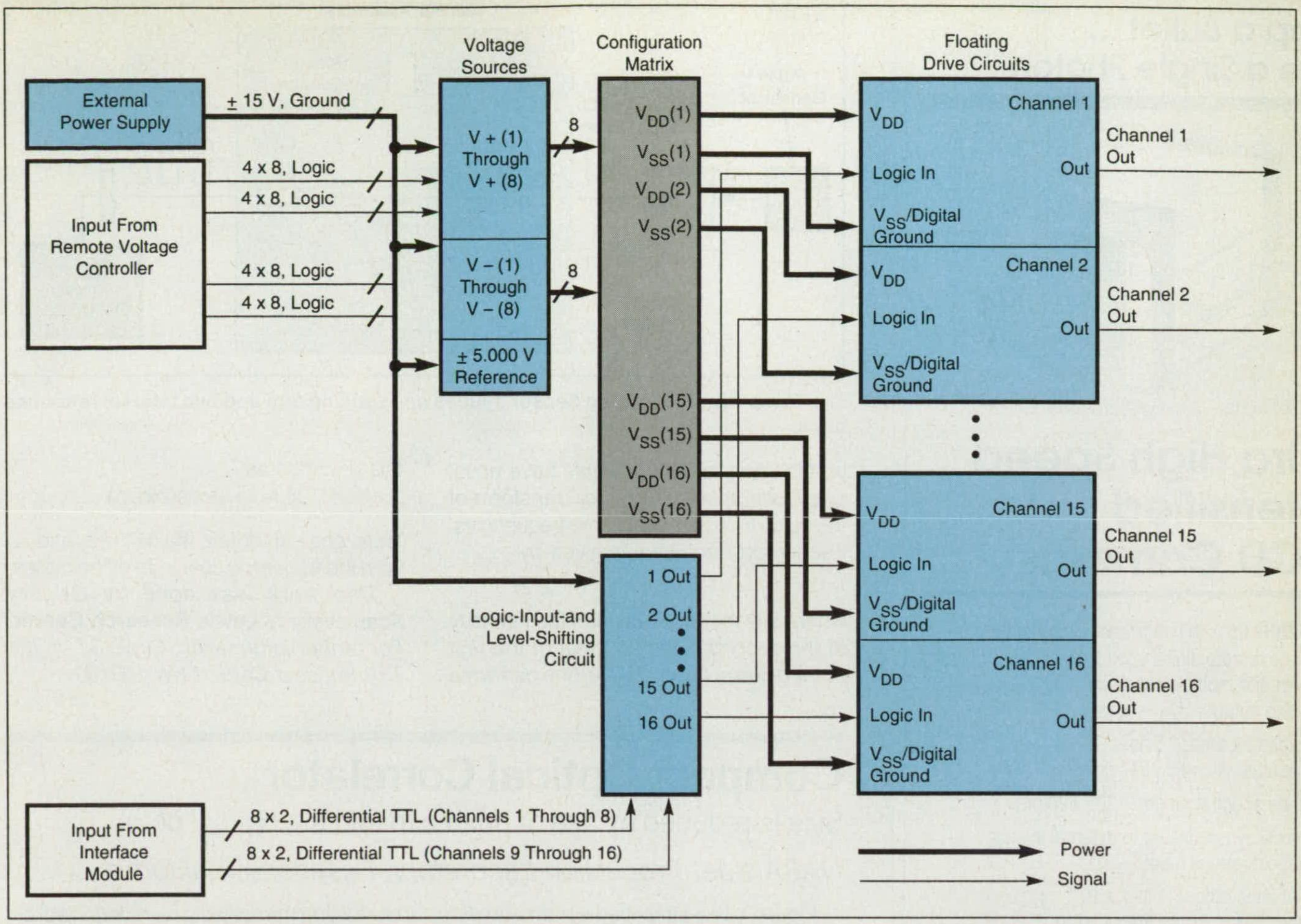
Prior general-purpose laboratory detector-array-driving systems tended to be expensive and bulky and to consume relatively large amounts of power, while prior compact, low-power driving circuits dedicated to specific arrays deployed in the field provided little or no adjustability of voltages. The present system offers the primary advantage (adjustability) of prior laboratory systems, but at a cost, power, and size more like those of prior dedicated, field-deployed systems.

The system includes three modules: an interface module, a remote voltage-controlling module, and a drive module. To reduce susceptibility to electromagnetic interference, the interface module incorporates (1) optocouplers that electrically isolate the source of timing signals from the rest of the system and (2) differential transistor/transistor logic (TTL) output drivers that provide additional isolation and a high degree of immunity to noise. Each channel in the drive module incorporates a large number of decoupling components to ensure fidelity of its output clock waveform and to provide a high degree of isolation between channels connected to the same voltage source.

The heart of the system is the drive module (see figure). This module contains a set of eight nominally positive and eight nominally negative voltage sources, which are digitally controlled voltage regulators (basically, digital-to-analog converters) that can be set at any voltage from +12 to −4 V (nominally positive) or +4 to −12 V (nominally negative) in increments of 62.5 mV. This module also contains a configuration matrix, which consists of 2 rows of 12 jumper pins for each of the 16 drive channels. By selection of the positions of the jumper plugs, one can choose any of the nominally positive or nominally negative voltage sources as the source of the drain supply voltage (V_{DD}) or the source supply voltage (V_{SS}), respectively, for the floating drive circuit in each channel.

A logic-input-and-level-shifting circuit accepts 16 input differential logic signals and converts them to the voltage levels for each floating drive circuit by means of analog switches. Each floating drive circuit consists of a special-purpose high-speed complementary metal oxide/semiconductor driver integrated-circuit chip and a number of passive components, which are mounted in sockets as needed to tailor the clock waveform to suit the application. A floating drive circuit can be made to supply a dc bias voltage by removal of the driver from its socket and substitution of a jumper plug that connects either V_{DD} or V_{SS} to the output pin.

The remote voltage-controlling mod-



The **Drive Module** is reconfigurable by use of jumper plugs (to select voltage sources) and controllable by externally generated logic signals.

ule (not shown in the figure) provides digital control signals to the 16 voltage sources on the drive module. The signals are generated by 16 pairs of 4-bit rotary hexadecimal switches.

The interface module (also not shown) accepts 32 single-ended logic signals from any source and provides 32 differential logic outputs — enough to control fully 2 drive modules, like the one described above. The inputs are electrically isolated from the outputs by use of high-speed optocouplers, thus providing the drive system with total immunity to interference from the source of logic signals.

This work was done by Peter K. Shu, Jeffrey W. Travis, and John T. S. Lee of **Goddard Space Flight Center**. *For further information,* ***write in 29*** *on the TSP Request Card. GSC-13517*

Three-Arm, Self-Referencing Fiber-Optic Sensor

The sensor reading is relatively immune to spurious variations in illumination and transmission.

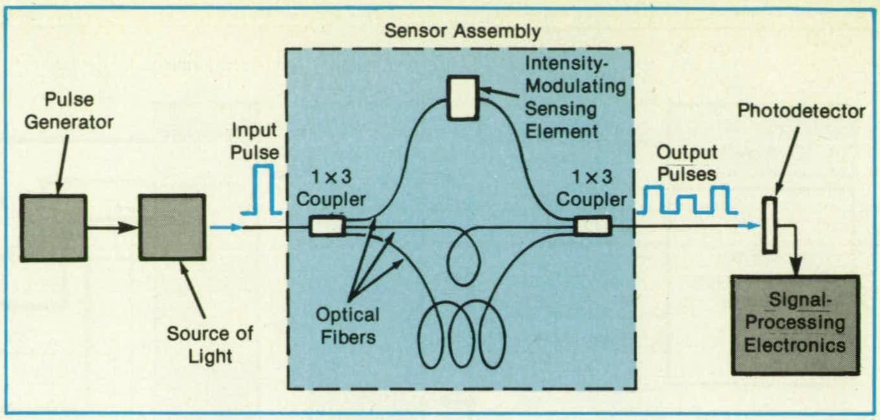
Lewis Research Center, Cleveland, Ohio

An intensity-modulating fiber-optic sensor produces an output signal that can be read with little interference from spurious variations in the intensity of the input illumination or in the transmittances of optical fibers and connectors. Heretofore, in using a typical intensity-modulating fiber-optic sensor, it has also been necessary to use a separate reference fiber-optic channel to compensate for such spurious variations. In this case, no separate reference channel is necessary; the sensor provides its own internal reference.

Illumination for the sensor is provided by a pulsed source of light. Pulses of light travel along an optical fiber into a sensor assembly that includes two 1 × 3 fiber-optic couplers and three optical fibers (see figure). After entering the sensor assembly through the left coupler, a pulse of light is split into three pulses, each traveling along one of the three fibers. The three fibers have different lengths chosen to delay the pulses by different amounts of time in equal increments, Δ; that is, after the pulses are recombined in the right 1 × 3 coupler, the first pulse emerges from the output optical fiber Δ before the second, which emerges Δ before the third. The intensity-modulating sensing element is incorporated in the arm with the fiber of intermediate length (the one that forms the second pulse).

The relevant data in the sensor readout are the ratios between the intensity of the second pulse and those of the first and third pulses. As long as the spurious fluctuations in intensity are characterized by times much longer than Δ, they do not affect the measured ratios. Thus, the ratios can be extracted and processed to obtain the sensed information.

One way to extract the ratios is by use of Fourier analysis of the output pulses. If, for example, the pulses are rectangular



The **Three-Arm Fiber-Optic Sensor** inludes one sensing arm and two internal reference arms.

and the first and third pulses have equal amplitude, then the Fourier transform of the pulse train is zero at some frequencies. Each such frequency is given by

$$f_o = (1/2\pi\Delta)\cos^{-1}(-a/2)$$

where a is the ratio between the intensity of the second pulse and that of the first or third pulse. Alternatively, one can write this equation as

$$a = -2\cos(2\pi f_o\Delta)$$

Thus, one can obtain the desired ratio, a, from the frequency spectrum of the pulses.

This work was done by Grigory Adamovsky of **Lewis Research Center**. *For further information, Circle 37 on the TSP Request Card. LEW-15019*

Compact Optical Correlator

Size is reduced by use of prisms to fold the optical path.

NASA's Jet Propulsion Laboratory, Pasadena, California

Figure 1 is a simplified schematic diagram of a prototype compact, lightweight Vander Lugt optical cross-correlator. This device was designed, assembled from commercial components, and tested to verify the feasibility of miniaturization for eventual incorporation into the navigational and/or control systems of autonomous vehicles. For example, an aircraft could be equipped with an optical correlator that would recognize a prescribed target and measure its position, so that the aircraft could be landed on the target under automatic control.

A telescope images the scene (possibly containing the target to be recognized) onto the writing side of a liquid-crystal light valve (LCLV). The diverging, coherent beam from a laser diode (the reading beam) is reflected from a polarizing beam-splitter cube and collimated, via a lens, onto the reading face of the LCLV. Upon reflection from the LCLV, the reading beam is modulated by the image of the scene. The same lens that collimates the reading beam onto the reading face of the LCLV also Fourier-transforms the image in the reflected beam.

Information on the target pattern to be recognized is embodied in a matched filter,

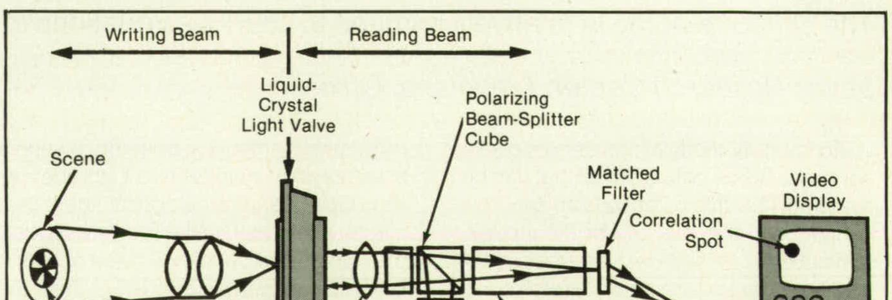


Figure 1. The **Optical Cross-Correlator** indicates the position of a target (if any) in the scene that matches the target encoded in the matched filter.

which is a holographic image of the target combined with a converging-beam holographic optical element. The reflected beam carries the Fourier transform of the scene to the matched filter, and the output correlation image is formed on a charge-coupled device or on an array of complementary metal oxide/semiconductor (CMOS) photodetectors, from whence the image is coupled to a video display. If a portion of the scene matches the target encoded in the matched filter, then a bright spot appears in the correlation image at the location of the matching object.

Miniaturization is achieved largely by using prisms to fold the optical path around the beam splitter. As shown in more detail in Figure 2, there are actually two beam-splitter cubes, one of which is polarizing. The beam-splitter cubes and three Porro prisms are cemented together into a solid module, thereby making the overall correlator assembly more compact and ensuring the permanent alignment of the cemented components with each other. All prism angles except one are either 45° or 90°, and the prisms can be aligned and cemented with a minimum of tooling. The entire optical assembly is only 45 mm high and 88 mm across the corners.

This work was done by Marija S. Scholl and Michael S. Shumate of Caltech, Richard L. Hartman of Hartman Associates, and Jeffrey A. Sloan and Donald W. Small of the Optical Corporation of America for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 48*** *the TSP Request Card.* NPO-18473

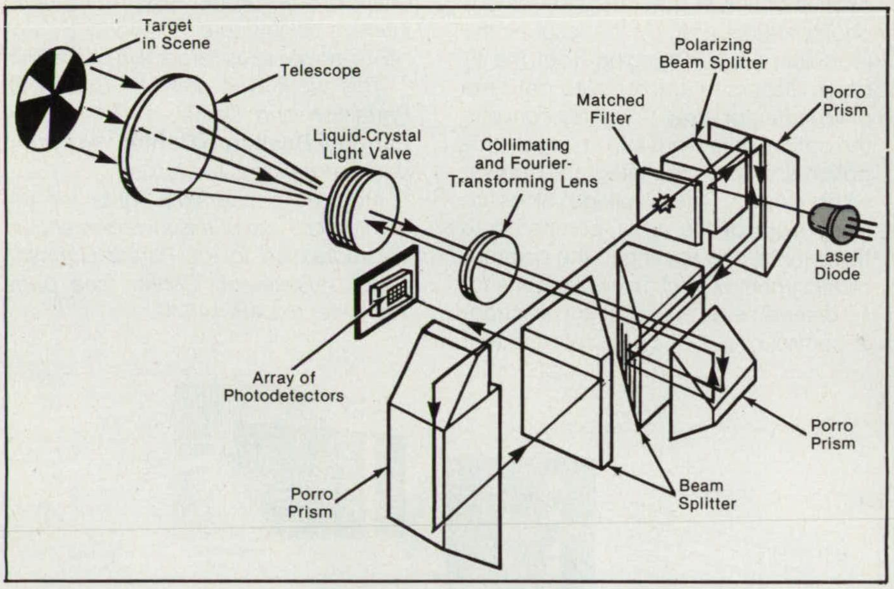


Figure 2. This **Exploded View** of the solid block correlator module shows how the optical path is folded to reduce the size of the correlator.

Wavelength-Division Multiplexing of Avionic Digital Control Signals

In comparison to serial time division multiplexing (TDM) communication systems, this one tolerates faults better.

Langley Research Center, Hampton, Virginia

A proposed wavelength-division multiplexing optoelectronic system aboard an aircraft would transmit digital control signals from a central flight-control computer via optical fibers to multiple distributed processors, actuators, and sensors. In comparison with the serial TDM communication systems currently used to control aircraft, this system would offer potentially higher data throughput, greater tolerance to transient induced faults, and lower bit-error rates. Additionally, like other fiber-optic communication systems, this system would be immune to electromagnetic interference at suboptical frequencies.

The figure illustrates some essential features of the transmitting and receiving subsystems. The light emitted by a broadband light-emitting diode would be directed onto a reflective holographic diffraction grating, from which it would be spectrally dispersed along the horizontal axis. Following dispersion, the light would be focused with a cylindrical lens onto a High Density Spatial Light Modulator (HDSLM). Dispersion of the light exists only along the horizontal axis, while no change in the spectrum occurs in the vertical direction.

The transmissivity (output power/input power) of each pixel in the HDSLM is controlled electrically by the application of a suitable voltage; e.g., 0 percent transmission for binary 0 and 100 percent for binary 1. Each pixel along the horizontal axis of the HDSLM modulates a unique spectral range, each range belonging to a specific bit of binary word. The horizontal collection of pixels defines a control/communication word designated for delivery to a particular actuator, and the like. Following optical modulation, light emanating from each pixel row is condensed and coupled into vertically stacked optical fibers that are linked to actuators, and the like.

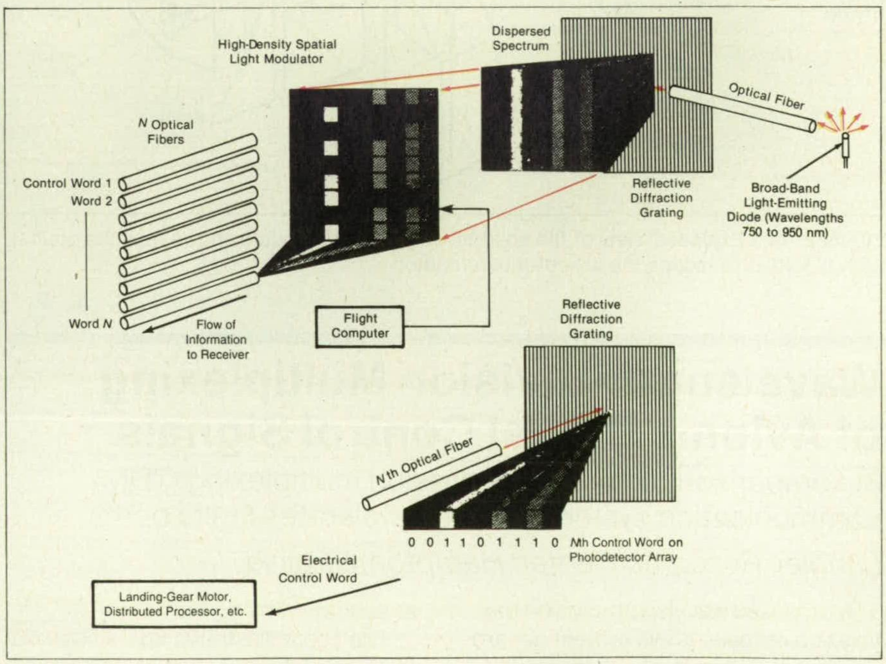
Each receiver would include the dispersive optics of the transmitter and a photodetector array. At the receiver, the modulated light emerging from the fiber is dispersed and focused onto the photodetector array. The array converts the optical data word into voltages propotional to the time-integrated power within each bit. These voltage values are shifted out of the array, compared to thresholds, and applied to the communication/control electronics of the intended receiver: e.g., applied to the electronic control circuit of an aircraft actuator such as an electrical motor that drives landing gear.

The enhanced fault tolerance of this system in comparison to serial TDM systems is partly due to shorter required data-recovery times. This is due to the availability of a complete data word at the receiver at all times (no TDM). When the data in the receiver electronics is corrupted by noise (e.g., a lightning strike), the data is immediately available for reloading.

An additional potential for reduced bit-error rates in comparison to serial TDM systems would arise from the ability to reduce the data-transmission rates of the individual bit channels without reducing the required aggregate rate (parallel communication). Slower bit-channel rates would result in reduced intersymbol interference and larger signal-to-noise ratios (larger eye openings).

This work was done by James D. Patterson and Daniel L. Palumbo of **Langley Research Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 10]. Refer to LAR-14849.



Wavelength-Division Multiplexing would offer advantages over time-division multiplexing for the transmission and reception of control signals aboard an aircraft.

Measuring Arc-Jet Velocity With Laser-Induced Fluorescence

Velocity is inferred from the Doppler shift in the fluorescence spectrum.

Lyndon B. Johnson Space Center, Houston, Texas

Figure 1 illustrates a dc constricted arc heater equipped with an apparatus that measures the velocity and temperature of the arc jet by use of laser-induced fluorescence in copper atoms. Copper atoms are available for use as tracers because they are sputtered continuously from the anode of the arc heater and become entrained in the arc flow. Two major advantages of this method of measurement are that it is relatively nonintrusive and that the laser beam can be focused to a micron-sized region to yield high spatial resolution.

The neodymium:yttrium aluminum garnet (Nd:YAG) laser pumps the dye laser. The frequency of the output of the dye laser is doubled to yield the final output laser beam, which has the wavelength of 327.5 nm needed to excite electrons in the copper atoms from the $^2S_{1/2}$ state to the $^2P_{1/2}$ state. The atoms then decay to the $^2D_{1/2}$ state by emitting photons (fluorescence) at 578.0 nm. As shown in Figure 2, coupling with the nuclear spins yields hyperfine separations of about 12 GHz in the $^2S_{1/2}$ state and 986 MHz in the $^2P_{1/2}$ state. These transitions help in identifying the laser-induced-fluorescence signal in the presence of noisy background signals.

The laser beam is incident at an angle $\theta = 60°$ or $\theta = 90°$ from the direction of flow. Laser-induced-fluorescence photons emitted perpendicularly to the flow are detected by a photomultiplier tube operating in photon-counting mode. The laser-induced-fluorescence spectrum is obtained by scanning the frequency of the dye laser under microprocessor control and plotting the photon-count and laser-frequency information on an *x–y* recorder.

The velocity of the flow is deduced from the shift in frequency or wavelength between the laser-induced-fluorescence spectrum measured at $\theta = 90°$ and the same spectrum measured at 60°. Starting from the fundamental equation for the longitudinal Doppler shift, it can be shown that in this case,

$$v = \frac{c}{\nu_0 \cos 60°} \Delta\nu$$

where v is the speed of flow, c is the

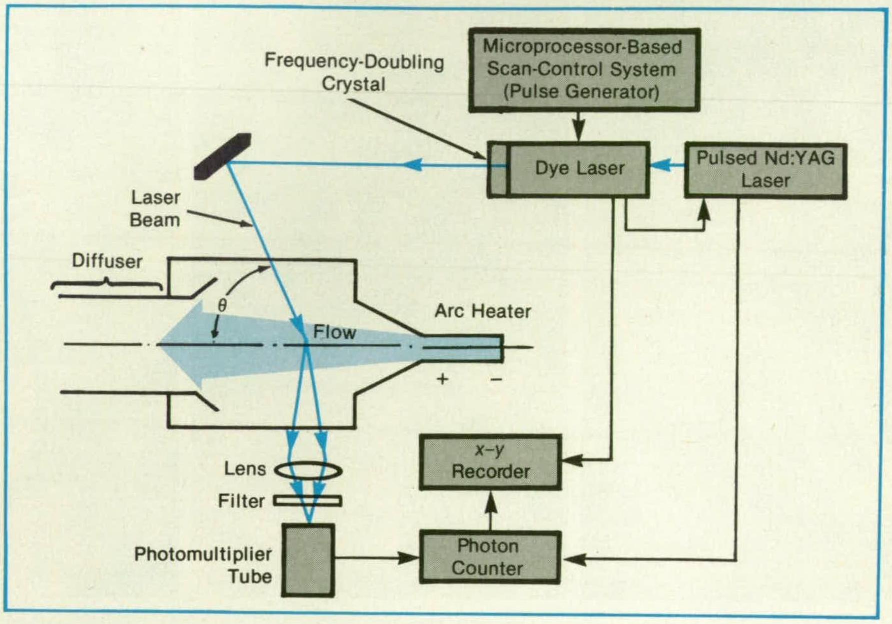


Figure 1. **Laser-Induced Fluorescence** in copper atoms entrained in the arc jet provides a spectrum from which temperature can be computed. The velocity of flow can be calculated from the shift in the spectrum between different angles of incidence.

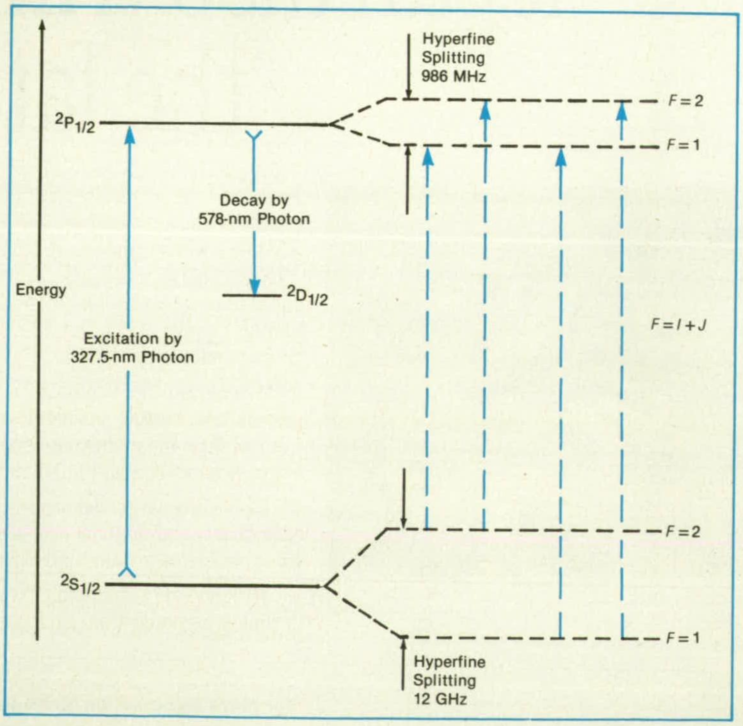


Figure 2. This **Partial Energy-Level Diagram** of the copper atom shows the levels involved in the laser-induced fluorescence and the hyperfine splitting of the $^2S_{1/2}$ and $^2P_{1/2}$ levels. This splitting can be used to identify the laser-induced-fluorescence signal in the presence of noise.

speed of light, ν_0 is unshifted frequency of the transition, the angle between the laser beam and the plasma flow is 60°, and $\Delta\nu$ is the shift in frequency.

The temperature is estimated by computing a least-squares best fit between the measured spectrum and a theoretical spectrum that includes the known spectral profile of the laser beam folded in with a quadruplet Gaussian profile for the four hyperfine levels. The least-squares best fit is obtained by choosing (1) a proportionality parameter in the theoretical spectrum and (2) the temperature (which is also a parameter of the theoretical spectrum), so as to minimize the sum of squared differences between the theoretical and measured spectral intensities.

This work was done by Eric H. Yuen and Carl D. Scott of **Johnson Space Center** *and Sivaram Arepalli of Lockheed Engineering and Sciences Co. For further information,* ***write in 72*** *on the TSP Request Card. MSC-21999*

Thermography and Ultrasonics Find Flaws in Composites

Flaws are first located in infrared imagery, then probed ultrasonically to reveal details.

Langley Research Center, Hampton, Virginia

Thermographic and ultrasonic techniques, applied sequentially, constitute the basis of a developmental method of nondestructive inspection of structures made of lightweight composite materials like carbon-fiber/epoxy-matrix laminates. The method, when fully developed, should enable the rapid detection and evaluation of damage and other flaws in composite structures. Unlike some other inspection methods, this one does not require access to both sides of a structure to be inspected; thus eliminating the tedious coordinated setup of interior and exterior instrumentation.

The first stage of an inspection by this method involves a combination of infrared thermography and digital image processing. An infrared camera is aimed at the composite panel or other structure to be inspected. The camera is connected to an image-data processor and a control computer. Flash lamps, also under control of the computer,

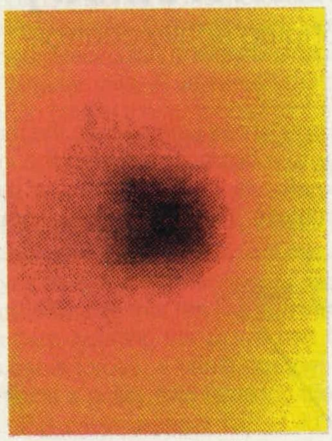


Figure 1. This **Processed Thermographic Image** of the surface of a through-the-thickness-reinforced carbon-fiber/epoxy panel 0.64 cm thick shows damage from the impact of a 1.27-cm-diameter aluminum ball at a kinetic energy of 41 J.

The system performance is such that optical pathlength variations in any 5-ms window are kept below the 10-nm RMS goal for optical delay rates up to 28 mm/sec, with a graceful degradation of performance at higher speeds, allowing the system to be used with ground-based optical interferometers with baselines exceeding 800 meters with negligible degradation of the signal-to-noise ratio for science observations.

This work was done by Mark Colavita, Braden E. Hines, and Michael Shao of Caltech for **NASA's Jet Propulsion Laboratory**. *The work was funded through a contract from the Naval Research Laboratory. For further information,* **write in 81** *on the TSP Request Card. NPO-18686*

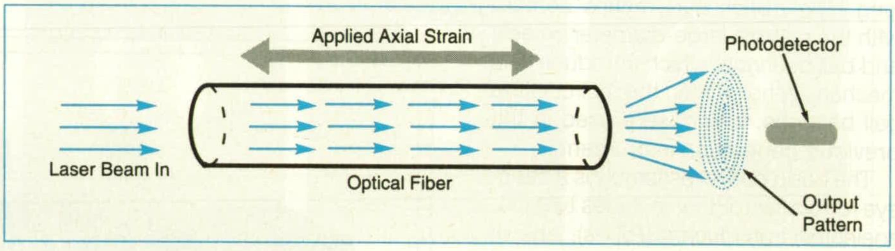
Fiber-Optic Strain Sensors With Linear Characteristics

Linearity would be obtained by appropriate choice of design parameters.

Langley Research Center, Hampton, Virginia

Fiber-optic modal domain strain sensors that would have linear characteristics over a wide range of strains have been proposed. These sensors were conceived in an effort to improve on older fiber-optic strain sensors.The outputs of the older sensors do not vary linearly with applied strains; that is, the older sensors can be regarded as having linear characteristics over a relatively small range of strains. However, computations of electromagnetic modes in two-mode optical fibers show that by appropriate choice of design parameters, outputs could be made to vary nearly linearly over a much wider range.

The figure illustrates a proposed fiber-optic sensor that could, for example, be embedded in a structure to measure axial strain. The radius of the fiber core and the indices of refraction of the core and cladding would be chosen by design so that the fiber would support two electromagnetic modes at the wavelength of light supplied by a laser. Furthermore, the fiber would be designed so that the difference of the phase shift between the two modes would be small — typically, less than 0.17 radian.



The Pattern of Light and Dark Areas at the output end of the optical fiber would be produced by interference between the electromagnetic modes in which the laser beam propagates in the fiber. The photodetector would monitor the intensity at one point in the pattern.

The fiber would be illuminated by the laser at one end, and interference between the electromagnetic modes would result in a modal pattern at the output end. A photodetector would monitor the intensity of light at one point in the pattern. Under the design conditions described above, this intensity would vary nearly linearly with axial strain over a strain interval much wider than that of older fiber-optic strain sensors.

This work was done by Claudio O. Egalon of Analytical Services and Materials, Inc., and Robert S. Rogowski of **Langley Research Center**. *For further information,* **write in 7** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquires concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 10]. Refer to LAR-14857.

Planar Poincaré Charts for Polarization Calculations

Stereographic projections yield planar charts for graphical analyses.

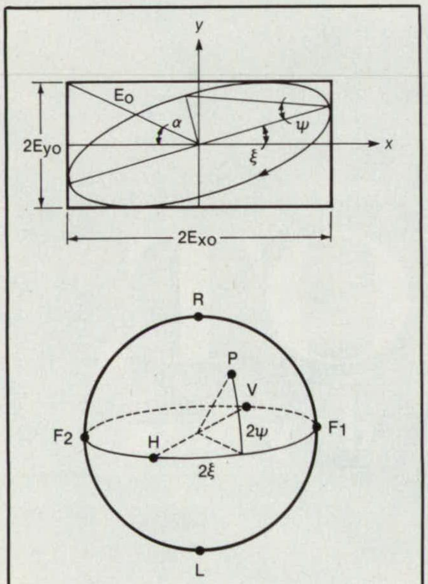
Langley Research Center, Hampton, Virginia

A new type of stereographic projection of the Poincaré sphere makes flat charts for use in graphical analyses of the polarization-transformation characteristics of optical components or systems. While such analyses can be performed on the surface of the Poincaré sphere, the planar charts are more practical to use and store.

A chart of this type can be used to predict for example, the polarization state at the output of a birefringent material for any arbitrary input polarization state. A chart represents the entire Poincaré sphere; previous planar projections represented only one hemisphere. With the new charts, analyses of some polarization-dependent optical components or systems, which analyses would otherwise require long formulas or complicated diagrams, can be reduced to simple graphical procedures. A computer program based partly upon the relationships among the polarization parameters and partly on the invariance of one of the projections under rotation can be used for accurate calculation and graphical display of transformations of the polarization state.

The polarization state of an elliptically polarized beam of light can be specified by the orientation of the major axis ξ, the ellipticity ψ, the amplitudes E_{xo} and E_{yo} of the components of the electric field along the *x* and *y* axes, respectively, and the phase δ. The same information can also be represented on the Poincaré sphere, on which the latitude represents 2ψ and the longitude represents 2ξ (see Figure 1).

A planar Poincaré chart of the new type is produced by the stereographic projection shown in Figure 2. A point *P* on the Poincaré sphere is projected onto point *P′* on a plane that bisects the sphere. The projection line is the straight



Notes:
1. "R" denotes right circular polarization.
2. "L" denotes left circular polarization.
3. "H" denotes horizontal linear polarization.
4. "V" denotes vertical linear polarization.
5. "F1" and "F2" denotes linear polarizations tilted at ±45°.

Figure 1. **Elliptically Polarized Light** can be represented in terms of the angle ξ of the major axis, and ellipticity angle ψ, and the amplitudes of the *x* and *y* components of the electric field. The same information can be represented on the Poincaré sphere as a point *P* at longitude 2ξ and latitude 2ψ.

line between point P and antipodal point S. Each hemisphere is projected separately; the two resulting circular projections are placed side by side to form a chart that represents both hemispheres. Alternatively, one projection can be put on a transparent chart and placed over the other one.

The form of the coordinate lines projected onto the plane depends on whether the projected hemispheres were obtained by bisecting the sphere along the equator or along a meridian. The choice of the bisecting plane depends on the type of material under analysis.

This work was done by Ken K. Tedjojuwono, William W. Hunter, and Stewart L. Ocheltree of **Langley Research Center**. *For further information,* ***write in 105*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-13975.

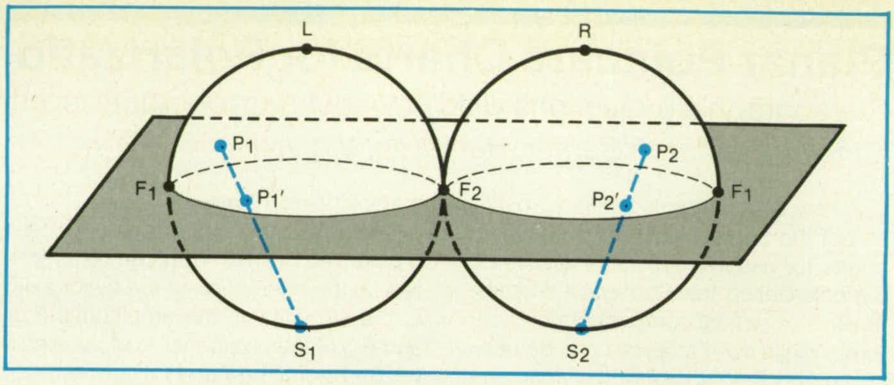


Figure 2. **Stereographic Projections** of the two hemispheres of the Poincaré sphere result in planar charts.

Tracking Polymer Cure Via Embedded Optical Fibers

Fourier-transform infrared spectroscopy reveals changing quantities of reactants.

Marshall Space Flight Center, Alabama

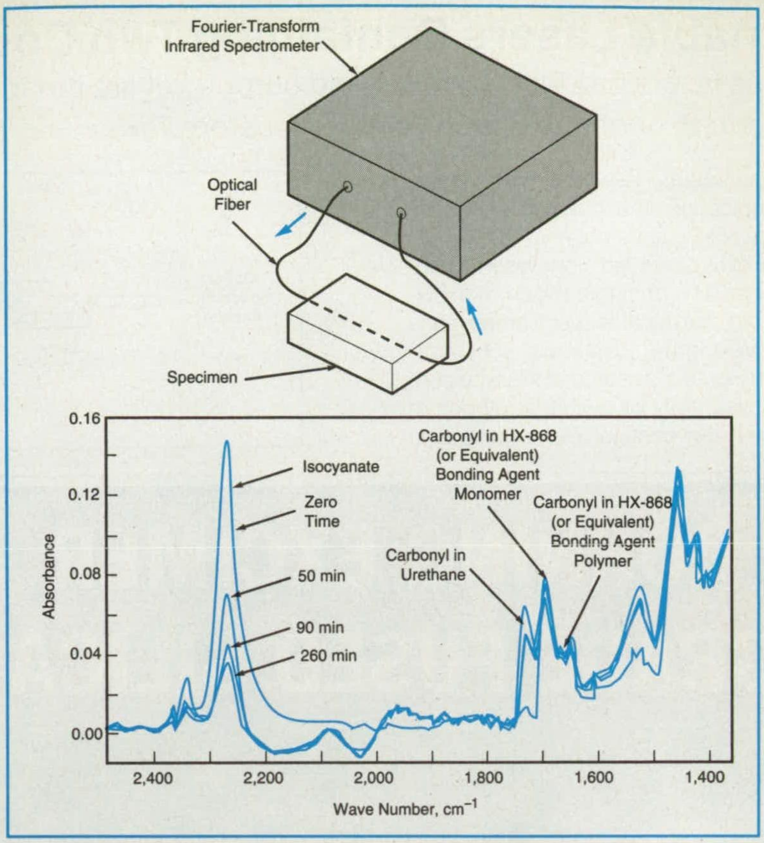
One or more optical fibers can be embedded in a specimen of a curing polymeric material to provide for nondestructive, in situ, local monitoring of the progress of the cure by use of Fourier-transform infrared spectroscopy (see figure). Infrared light is fed to the input end of the embedded optical fiber and of another optical fiber that is not embedded. The embedded fiber acts as an imperfect waveguide in that some of the light in the fiber travels in the evanescent-wave mode, in which it interacts with a thin layer of the surrounding material.

Most of the light is reflected back into the fiber, where it continues to travel toward the output end. Some of the light is absorbed at wavelengths char-

acteristic of the molecular bonds of various chemical constituents present in the material. The spectrum of light emerging from the output end of the embedded fiber is analyzed and compared with the spectrum of light from the output end of the nonembedded fiber to determine the infrared absorbance spectrum of the specimen. Spectra obtained in this way at various times during the curing process can also be combined with data from ultrasonic, thermographic, and dielectric-impedance monitoring, and other measurement techniques to obtain a more complete characterization of the progress of the curing process.

The lower part of the figure shows some representative Fourier-transform infrared spectra taken at various times during the cure of a specimen of polymeric material used as a liner to bond a propellant to a rocket-motor case. The spectra in this case include absorption peaks characteristic of the chemical bonds that are of greatest interest for monitoring the cure.

This work was done by David L. Dean and T. Fred Davidson of Science Applications International Co. of Atlantic Research Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 8*** *on the TSP Request Card. MFS-28620*



Fourier-Transform Infrared Spectroscopy can be applied in the interior of a specimen of material by bringing the infrared light through the specimen in an optical fiber. The light interacts with the material via the evanescent-wave effect.

Tunable Lasers Containing Two Coupled Laser Diodes

These lasers produce narrow-band output, yet are tunable over a broad range.

Lyndon B. Johnson Space Center, Houston, Texas

Experiments have confirmed theoretical indications that one can exploit the phase-locking and frequency-pulling behavior of two coupled diode lasers to obtain a source of single-mode, narrow-band radiation tunable over a broad range of wavelengths. As shown schematically in Figure 1, a source of this type consists essentially of two laser diodes of Fabry–Perot configuration coupled via a short optical fiber with microlenses at both ends. Although coupled optically, the laser diodes are subjected to independent electrical excitations.

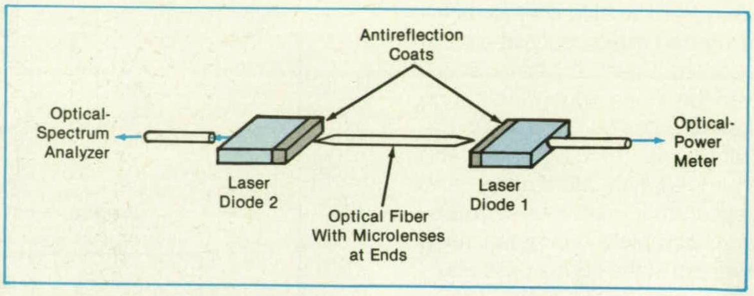


Figure 1. **Laser Diodes Coupled by an Optical Fiber** exhibit frequency-pulling and phase-locking behavior that can be exploited to obtain spectrally narrow but broadly tunable output.

The laser diodes used in the experiments were commercial units that nominally emit at a wavelength of about 1.3 µm. The optical fiber was of a single-mode type and was 19 mm long. The microlenses were formed on the ends of the fiber by the fusion-pulling technique. The facets of the laser diodes that faced the fiber microlenses were antireflection coated and had reflectivity <1 percent.

To assure reliable operation, thermoelectric coolers were attached to the laser-diode submounts. Piezoelectrical/mechanical micropositioners aligned the fibers and laser diodes with each other to submicron accuracy. With the proper alignment and microlenses of optimum radius (found experimentally to be about 10 µm), the coefficients of coupling between the laser diodes and the fiber ranged from 50 to 56 percent.

Several two-coupled-laser sources were fabricated for the experiments, using laser diodes from two different manufacturers. The tuning-and-locking wavelength ranges varied among units from a low of 110 Å to a high of 140 Å. Figure 2 shows the tuning-and-locking response of a typical source, in which one laser diode was supplied with a fixed current of 30 mA while the other was supplied with four different currents. The experiments also indicated that side modes are suppressed by at least 20 dB over the entire tuning range and that the emission spectrum is less than 0.02 Å wide. In an additional experiment in which two laser diodes were coupled

through an integrated optical waveguide on a substrate of $LiNbO_3$, the tuning-and-locking range was slightly broader than in the fiber-coupling experiments.

This work was done by J.J. Pan of E-Tek Dynamics, Inc. for **Johnson Space Center**. *For further information,* ***write in 4*** *on the TSP Request Card. MSC-21840*

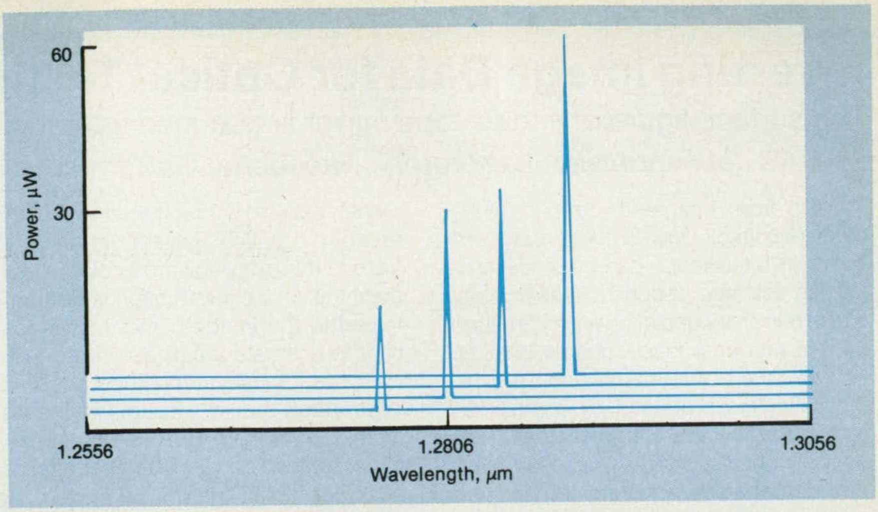


Figure 2. This **Turning-and-Locking Response** was elicited from two lasers coupled as shown in Figure 1. The current supplied to one of the lasers was set at four different values, resulting in outputs at four different wavelengths.

Imaging Hydrogen Leaks With Raman Scattering

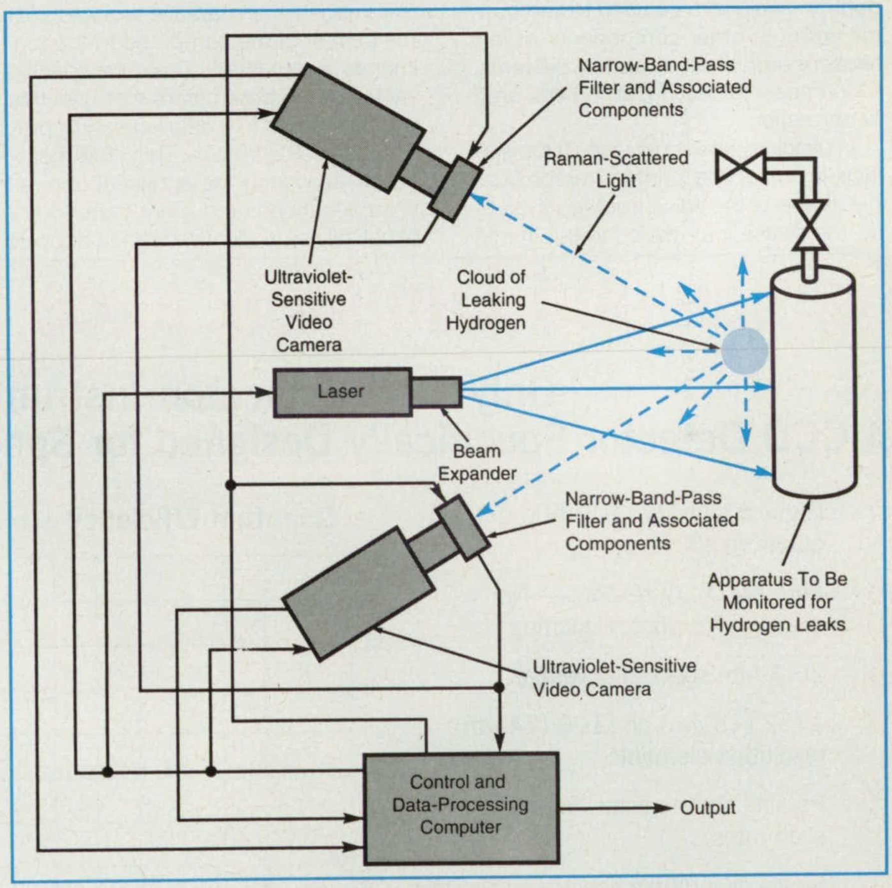
Hydrogen would be distinguished by its appearance at a selected wavelength.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed spectral imaging system would be used to detect leaking hydrogen from distances of 100 ft (about 30 m) or more. By indicating potentially explosive concentrations of hydrogen in air, the system could contribute to safety at facilities that produce and handle hydrogen; for example, at fueling stations for hydrogen-burning automobiles of the near future.

The figure illustrates one version of the system, which would include an excimer laser operating at a suitable ultraviolet wavelength — preferably 248 nm. Typically, the laser would provide 400-mJ pulses at a repetition rate of 250 Hz — corresponding to an average output power of 100 W. The laser beam would be spread out to illuminate the entire apparatus from which hydrogen might leak. This eliminates the risk of the laser causing ignition of the hydrogen and also maintains eye-safe laser enery densities. Raman scattering from the leaking hydrogen (if any) would shift the wavelength to 276.5 nm, which is in the solar-blind part of the electromagnetic spectrum. The scene would be monitored by several ultraviolet-sensitive video cameras, possibly similar to infrared-sensitive video cameras used for thermal imaging. Each camera would be equipped with a narrow-band-pass optical filter to admit only the 276.5-nm Raman-scattered light.

Operation in the solar-blind wavelength range would help to maintain an adequate signal-to-noise ratio. The signal-to-noise ratio could be increased further by operating the laser and camera in synchronism at a typical pulse-repetition rate of 250 Hz and building the image up in the camera by integrating sequences of 250 pulses into 1-second frames.



The **Video Cameras Would Form Images** of leaking hydrogen by use of Raman scattering of the laser beam from hydrogen.

The video cameras would be arranged in stereoscopic pairs to synthesize three-dimensional views and enable the precise location, to within a few centimeters, of the cloud(s) of leaking hydrogen. Images could also be formed with and without the filters in place so that the Raman-scattering image of the hydrogen could be superimposed on an ordinary visible-light image of the apparatus being monitored.

This work was done by Iain S. McDermid of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 23*** *on the TSP Request Card. NPO-18613*

Inverting Image Data for Optical Testing and Alignment

The surface figure of a telescope mirror is deduced from the images it produces.

NASA's Jet Propulsion Laboratory, Pasadena, California

Data from images produced by a slightly incorrectly figured concave primary mirror in a telescope can be processed into an estimate of spherical aberration of the mirror, by use of an algorithm that finds a nonlinear least-squares best fit between the actual images and the synthetic images produced by a multiparameter mathematical model of the telescope optical system. The estimated spherical aberration, in turn, can be converted into an estimate of the deviation of the reflector surface from its nominal precise shape. The algorithm was devised as part of the effort to determine the error in the surface figure of the primary mirror of the Hubble space telescope, so that a corrective lens can be designed. Modified versions of the algorithm could also be used to find optical errors in other components of this telescope or of other optical systems, for purposes of testing, alignment, and/or correction.

In principle, one could recover the surface figure of the primary mirror from the shape of the wave front (equivalently, the phase information in the image plane), assuming that the effects of the rest of the optical system on the wave front in the exit pupil are known. However, the phase information is not contained in the images, and it is necessary to estimate the phase information from the intensity (amplitude squared) information that is available in the images. For this purpose, the multiparameter mathematical model is constructed to represent the optical system, its effect upon shape of the wave front, and the images that it produces.

This model incorporates multiplane diffraction and detailed ray tracing. The parameters of the various optical components and degrees of freedom in the model are adjusted, and the resulting computed images compared with the real images in an iterative process until the best fit of the computed to the real images is obtained. Then the specific values of the parameters that give this best fit amount to a detailed optical prescription of the system. Thus, this method of recovering the spherical aberrations, locations, and other parameters of optical components has been dubbed "prescription retrieval."

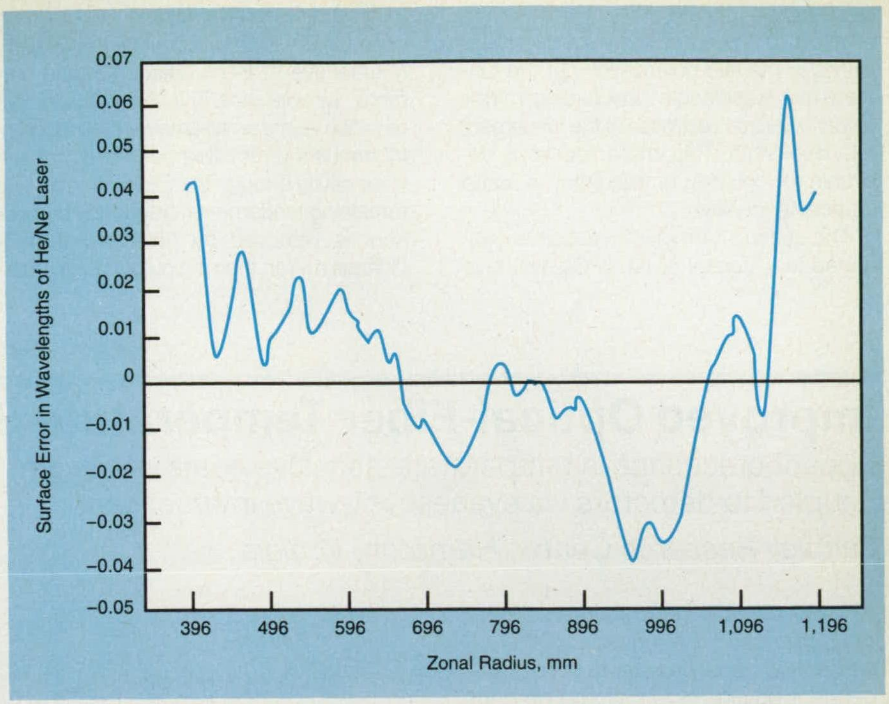
Some details of the model and of the nonlinear least-squares best-fit technique are worth noting. The model is partitioned into two submodels. One submodel incorporates the parameters of the telescope and represents the complex wave front in the exit pupil as a finite series in the first 28 Zernike polynomials. This submodel can even account for previously unknown imperfections of the primary mirror (see figure).

The other submodel includes parameters that account for the integrated intensity and background level of the image, the image centroids that adjust the origin of the simulated detector before pixelization of the simulated response of the system to an input point source, the point-spread function (PSF), and the image-dependent source field angles and despacing of the secondary mirror.

The best-fit parameterization is defined as the one that minimizes the weighted sum of the squares of the pixel-by-pixel differences between the modeled and the actual images. The weight of the contribution of each pixel to this sum is

the reciprocal of the variance of the intensity in the pixel. This variance is, in turn, the sum of squares of the Poisson noise (which, in this case, is the actual intensity), the readout noise of the charge-coupled-device imaging detector, and random variations in the flat-field correction.

This work was done by Michael Shao, David Redding, Jeffrey W. Yu, and Philip J. Dumont of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 106*** *on the TSP Request Card. NPO-18747*



The **Error of the Surface Figure** of the primary mirror, as obtained from interferograms and plotted here as reduced to radial-zone form, can be incorporated into the mathematical model to refine the computed phase error and distortion of the wave front in the exit pupil. Accounting for this zonal surface error has been found to reduce the sum -square error measure by about 5 percent — indicating the accuracy of the fit is increased.

Diode-Pumped, Q-Switched, Frequency-Doubling Laser

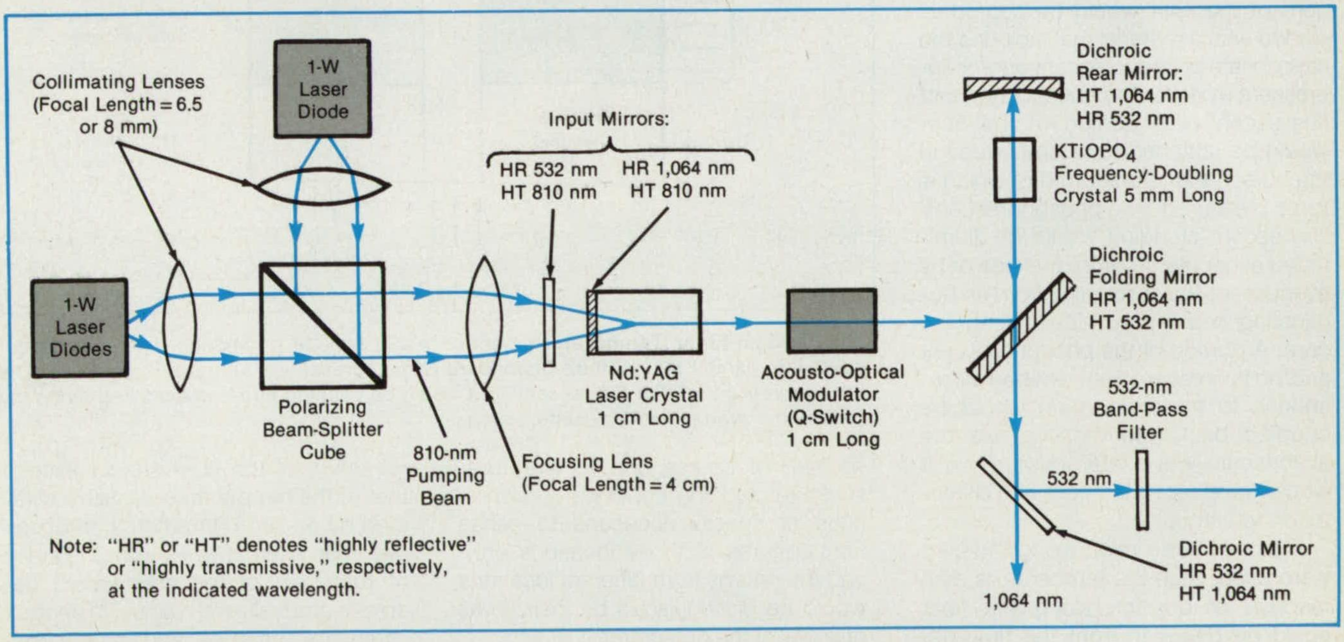
A folded resonator confines the double-frequency radiation to a portion of the laser cavity.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental Q-switched, diode-pumped, intracavity-frequency-doubling laser generates pulses of radiation at a wavelength of 532 nm from excitation at 810 nm. The principal innovative feature that distinguishes this laser from others of its type is pulsed operation of the laser at pulse-repetition frequencies higher than those reported previously.

The laser (see figure) includes a neodymium:yttrium aluminum garnet (Nd:YAG) laser crystal and an acousto-optical modulator, which serves as the Q-switch. Pump light at a wavelength of 810 nm is supplied by two 1-W laser diodes, the temperatures of which are controlled. The outputs of the diodes are partially collimated by lenses, combined in a polarizing beam-splitter cube, and focused through dichroic input mirrors onto the Nd:YAG laser crystal. Both input mirrors are highly transmissive at the 810-nm pump wavelength; one is attached to the Nd:YAG crystal and is highly reflective at the fundamental Nd:YAG laser wavelength of 1,064 nm, while the other is highly reflective at the second-harmonic wavelength of 532 nm and serves to protect the laser diodes against any Q-switched second-harmonic radiation that might be propagated back through the other input mirror.

The folding mirror is highly reflective at the fundamental laser wavelength and highly transmissive at the second-harmonic



The **Folded Resonator** keeps most of the second-harmonic (532-nm) radiation away from the Q-switcher, laser crystal, and laser diodes.

laser wavelength. By virtue of a difference of about 0.6 percent between its reflectivities in the two polarizations at the fundamental wavelength, the folding mirror favors polarized oscillation at the fundamental wavelength. This characteristic is desirable for doubling of frequency in some intracavity crystals.

The second-harmonic radiation is generated in a crystal of $KTiOPO_4$, which is located between the folding mirror and a concave spherical rear mirror that is highly reflective at the fundamental and harmonic wavelengths. The second-harmonic radiation plus a small amount of fundamental-frequency radiation passes out of the laser cavity through the folding mirror. The remaining fundamental-frequency component is removed by reflection from a dichroic mirror; then the output beam passes through a final 532-nm band-pass filter. In an experiment with a pump power of 2 W, a 532-nm output beam of 340 mW at a pulse-repetition frequency of 25 kHz was produced.

This work was done by Hamid Hemmati and James R. Lesh of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 78*** *on the TSP Request Card. NPO-18535*

Improved Optical-Fiber Temperature Sensors

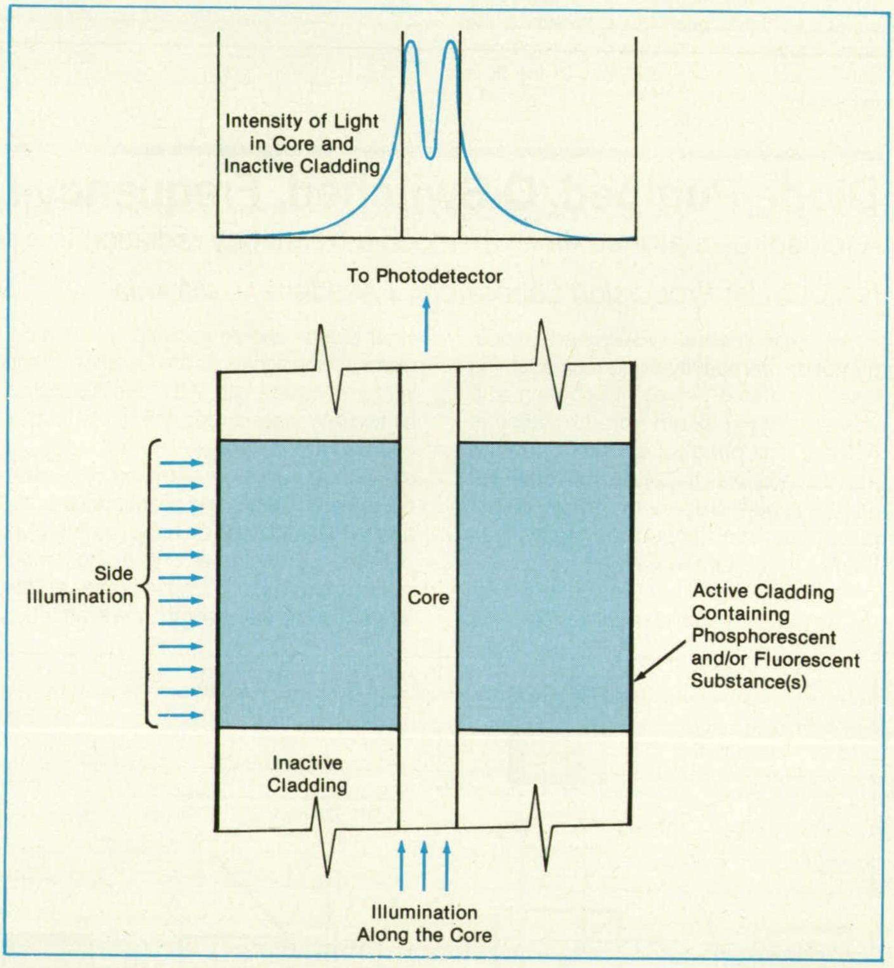
Phosphorescence in temperature-sensitive coats would be coupled to detectors via evanescent-wave interactions.

Langley Research Center, Hampton, Virginia

In optical-fiber temperature sensors of a proposed type, phosphorescence and/or fluorescence in temperature-dependent coating layers would be coupled to photodetectors. The phosphorescent and/or fluorescent behavior(s) of the coating material(s) would depend on the temperature; the coating material or mixture of materials would be selected so that one could deduce the temperature from the known temperature dependence of (1) the phosphorescence and/or fluorescence spectrum, and/or (2) the characteristic decay of fluorescence.

The basic optical configuration (see figure) is the same as that of the optical-fiber chemical detectors described in "Making Optical-Fiber Chemical Detectors More Sensitive" (LAR-14525), NASA Tech Briefs, Vol. 17, No. 3 (1993), page 77. At the location(s) where temperature is to be measured, the bare core of the fiber would be coated or claded with a material that includes the appropriate phosphorescent and/or fluorescent mixture. The phosphorescent/ fluorescent-clad portion of the fiber would be attached to or embedded in the object, the temperature of which is to be measured. The phosphorescent/ fluorescent cladding would be illuminated either directly from the side or by evanescent-wave coupling from an illuminating beam transmitted along the core. A portion of the phosphorescent and/or fluorescent light emitted in response to the illumination would be coupled back into the core via the evanescent-wave interaction; then it would travel along the core to a detector or detectors.

If pulsed illumination along the core were used, then the temperature as a function of position along the fiber could be deduced from the time-dependent phosphorescent/fluorescent response. Of course, the temperature-sensitive cladding could be applied in rings at specific locations to sense temperatures at those locations only, and the returns from different locations would be distinguished by their times of arrival at the detector(s).



This **Optical-Fiber Temperature Sensor** would include a cladding containing molecules that exhibit temperature-dependent phosphorescence and/or fluorescence. The phosphorescent and/or fluorescent light would be coupled into and launched along the core by the evanescent-wave interaction.

For greatest efficiency, the index of refraction of the core should exceed that of the temperature-sensitive cladding by as large an amount as possible. In an alternative version, the index of refraction of the fiber would decrease gradually with radius. In another alternative version, additional phosphorescent and/or fluorescent material

would be embedded in the core.

This work was done by Robert S. Rogowski of **Langley Research Center** *and Claudio O. Egalon of Analytical Services and Materials, Inc. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 10]. Refer to LAR-14647.

Ethylene-Vapor Optrodes

Porous optical fibers include sensing regions filled with reagents.

John F. Kennedy Space Center, Florida

Optical-fiber chemical sensors (optrodes) are being developed to measure concentrations of ethylene in air in enclosed artificial plant-growth environments. Such measurements are needed because ethylene acts as a plant-growth hormone that can affect growth at concentrations ≤ 20 parts per billion.

It is possible to measure concentrations of ethylene and other simple hydrocarbons by use of instruments like gas chromatographs and photoionization detectors, but these instruments are large. The optrodes are small, but exhibit sensitivities comparable to those of the larger instruments. Unlike the larger instruments, optrodes can be operated safely in potentially explosive atmospheres and they neither cause, nor are susceptible to, electrical interference at suboptical frequencies.

The developmental optrodes are made with state-of-the-art porous glass and porous polymer optical fibers. The sensing region of an optrode is a small (typically, 0.5 cm long and 250 μm in diameter) integral part of its optical-waveguide structure where a reagent has been cast into the pores. The reagent is a substance, the optical absorption spectrum (basically, the color) of which changes in the presence of ethylene.

Air from the surroundings, containing ethylene, enters the pores and interacts with the reagent. The intensity of the interaction is enhanced by the large interactive surface area provided by the pores. The change in the color of the reagent changes the spectrum of a beam of light that propagates along the fiber. The change is monitored by a colorimetric instrument at the output end of the fiber.

In laboratory tests, optrodes of this type have exhibited sensitivities to ethylene at concentrations ≤100 parts per billion. The readings of these sensors were highly linear and reproducible. On the basis of the cost of materials and ease of fabrication of optrodes, it appears that sensor systems, each consisting of multiple fibers deployed from a single analytical interface unit, would be less expensive than the conventional large instruments are.

This work was done by Mary Beth Tabacco and Quan Zhou of Geo-Centers, Inc., for **Kennedy Space Center**. *For further information,* ***write in 22*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 24]. Refer to KSC-11579.

Pinhole Calibrator for Particle-Sizing Instrument

Pinholes provide known, consistent diffraction patterns.

Lewis Research Center, Cleveland, Ohio

The rotating-pinhole calibrator is designed for use in calibrating and testing an optical instrument that measures the sizes of cloud droplets, dust particles, and other small (of the order of microns) particles suspended in flowing air. The rotating-pinhole calibrator is easily attachable to the particle-size-measuring instrument (see Figure 1) and is suitable for both quick verification of calibration in the field and detailed calibration studies in the laboratory. The calibrator can be used to determine such operating parameters of the instrument as optical collection angles, depth of field, profile of the laser beam used to measure the particles, and response to the trajectory of a particle. The calibrator can also be used to align the instrument.

Prior to the development of the rotating-pinhole calibrator, it was not possible to verify calibrations of optical particle-size-measuring instruments aboard aircraft, in wind tunnels, or elsewhere in the field: calibrations could be performed only in the laboratory, by blowing water droplets or glass beads of known size through the laser beams of the instruments. The glass-bead method can be expensive and yields less-accurate calibrations because the sizes of beads vary. The water-droplet method is time-consuming, the droplet generator clogs frequently, and it is difficult to generate droplets smaller than 50 μm.

The rotating-pinhole calibration method does not entail the disadvantages of either of the prior methods. A disk that contains a pinhole of known size is rotated so that the pinhole passes repeatedly through the laser beam of the instrument under test as the instrument is operated. The diffraction of light by the pinhole simulates the scattering of light from particles as they pass through the instrument. The intensity of light diffracted by a pinhole can be calculated to high accuracy by use of the well-known Fraunhofer theory of diffraction.

Thus, the rotating-pinhole calibrator provides a predictable and repeatable stimulus to which the response of the instrument can be measured easily. The response of an instrument should be repeatable when the same pinhole passes repeatedly through its laser beam; a change in the response indicates a shift in the calibration.

The response of an instrument is predictable because of the development of a transfer function that expresses the relationship between the amount of light diffracted from a pinhole and the amount of light scattered from a particle. In the example of Figure 2, the transfer function shows that a pinhole that has a diameter of 15 μm scatters the same amount of light into the collecting optics of the instrument as does a water droplet that has a diameter of about 9 μm.

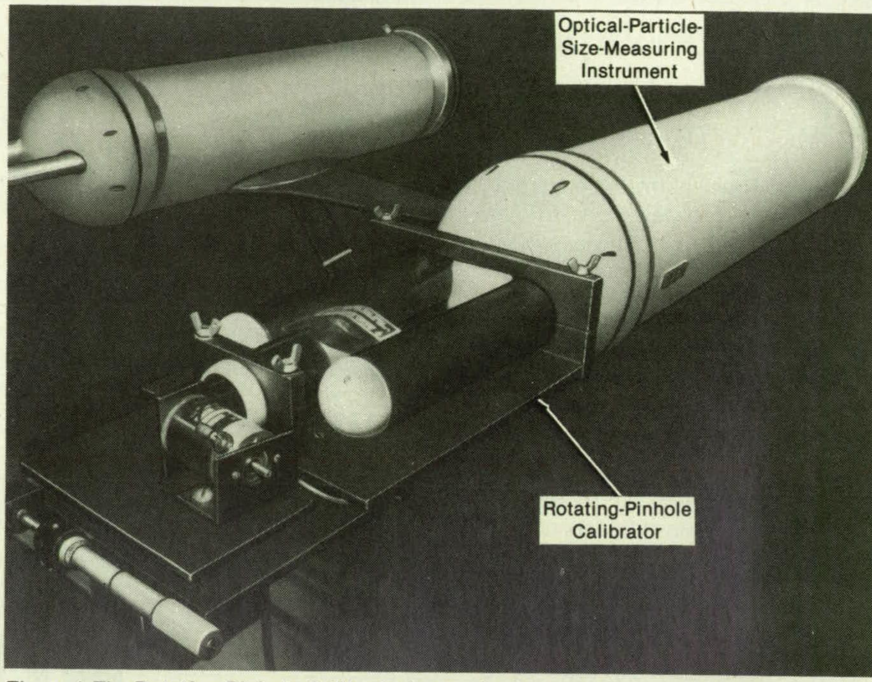


Figure 1. The **Rotating-Pinhole Calibrator** is attached to an optical particle-size-measuring instrument in the NASA Lewis Icing Research Tunnel.

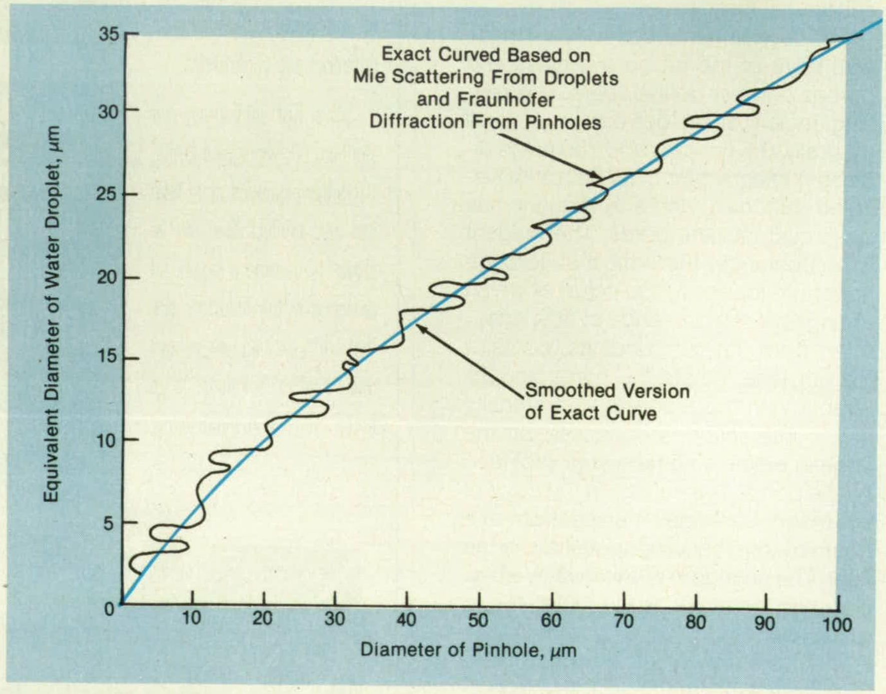


Figure 2. This **Transfer Function** shows those diameters of a pinhole and of a water droplet that scatter equal amounts of light into the collecting optics of one optical particle-size-measuring instrument.

Unlike glass beads and water droplets, a pinhole can be reused any number of times without risk of variation in its diffraction pattern. Furthermore, the size of a pinhole (unlike that of a glass bead) can be chosen precisely and at will; pinholes with diameters from 100 down to 1 μm can be purchased.

This work was done by Edward Hovenac for **Lewis Research Center**. *For further information,* ***write in 82*** *on the TSP Request Card.*
LEW-15286

Internal Standards for FTIR Analysis of Isocyanurates

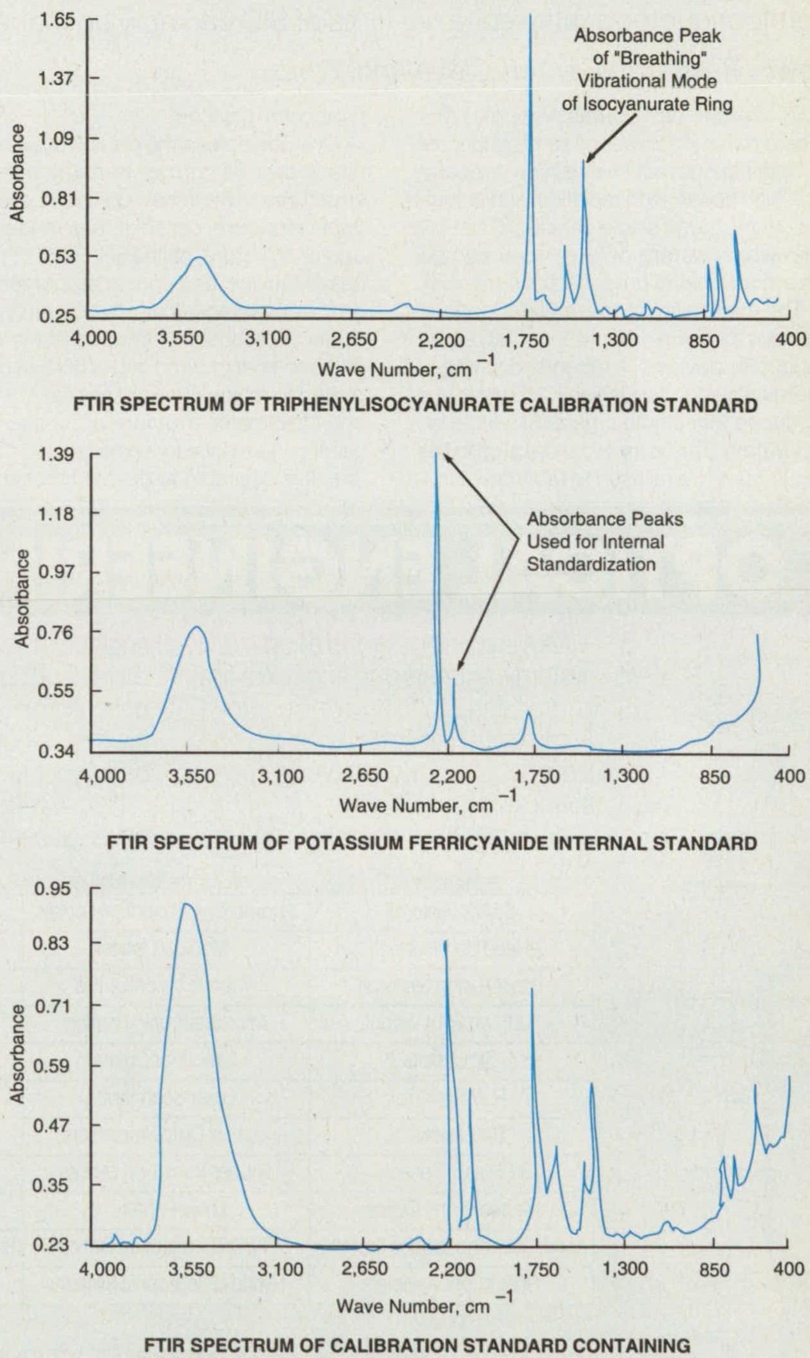
The concentration of isocyanurate in polyurethane foam can be measured.

Marshall Space Flight Center, Alabama

The concentration of isocyanurate in a polyurethane foam can be determined from Fourier-transform infrared (FTIR) spectroscopy of a sample mixture that contains both the foam and an internal standard of potassium ferricyanide. An internal standard is needed in FTIR spectroscopy because the sample mixture is pressed into a KBr window, and the resultant optical-path length through KBr is indeterminate. Quantitative analysis of isocyanurate in polyurethane foam is important because the concentration of isocyanurate affects the chemical and physical properties of the foam, and correlations between the concentration and the properties can be used to optimize foam formulations.

In an experiment, triphenylisocyanurate was synthesized by trimerization of phenylisocyanate in the presence of a quaternary ammonium salt, which acts as a catalyst. The trimerization was performed by heating an *orthox*-ylene solution of the phenylisocyanate plus a small amount of the catalyst to reflux. The triphenylisocyanurate formed as a crystalline precipitate, which was then washed in heptane and dried.

The FTIR spectra of samples containing triphenylisocyanurate were measured to establish standards with potassium ferricyanide used as an internal standard. In preparation for these measurements, an internal-standard powder mixture of 0.3 weight percent potassium ferricyanide in infrared-grade potassium bromide was prepared by grinding these two ingredients together in a ball mill, and various stock-standard powder mixtures of 0.5 to 3.0 weight percent of triphenylisocyanurate in potassium bromide were prepared similarly. A mixture of 1 part by weight of the internal-standard mixture and 0.045 part by weight of each stock-standard mixture was then prepared, and its FTIR absorbance spectrum was measured. The spectra thus obtained were evaluated to determine the absorbance of the isocyanurate ring in the wave-number range of 1,450 to 1,370 cm^{-1}. This range contains a



These **Infrared Spectra** contain characteristic peaks that can be used to calibrate FTIR measurements of isocyanurates in polyurethane foams.

peak at 1,410 cm^{-1}, representing a "breathing" (expanding-and-contracting) vibrational mode of the isocyanurate ring. The spectral range used for internal standardization was 2,130 to 1,960 cm^{-1}; the internal standard produces absorbance peaks in this range at 2,120 and 2,027 cm^{-1} (see figure). From these spectra, a calibration curve with a correlation coefficient of 0.999 was generated.

The use of potassium ferricyanide as an internal standard can be extended to other infrared spectral analyses of solids in which quantitative results are required. The internal-standard method eliminates the need to know the thickness of the sample. (Thickness would otherwise have to be known in quantitative analysis because absorbance is a function of the quantity of analyte in the infrared beam and is related to concentration by Beer's law.) The synthesis of triphenylisocyanurate can be extended to the production of pure compounds from substituted phenylisocyanates that can be added to test foam formulations to determine improvements in thermal properties with pure or substituted triphenylisocyanurate.

This work was done by William C. Solomon, Earl Pratz, and Doris A. Smith of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 74*** *on the TSP Request Card. MFS-28709*

Chemical Vapor Deposition of Silicon Carbide

Semiconductor-quality epitaxial films of SiC can now be made.

Lewis Research Center, Cleveland, Ohio

Silicon carbide (SiC) has properties that should make it a superior semiconductor for applications that involve high temperature, high power, high radiation, and/or high frequency. Large single-crystal SiC boules from which wafers of large area can be cut are now being produced commercially. The availability of these wafers opens the door for the development of SiC semiconductor devices. A recently developed chemical vapor deposition (CVD) process produces thin single-crystal SiC films on SiC wafers. This is an essential step in the sequence of steps used to fabricate semiconductor devices.

One obstacle to the growth of SiC crystals is that SiC grows in many different structures. The most common are the cubic structure, called 3C or β, and a hexagonal structure, called 6H. Each of these has electronic and optical properties that give it advantages over the others in particular applications. For example, the wider electron-energy-band gap of 6H can be exploited to make blue-light-emitting diodes, and the simpler structure of 3C may yield better performance for some devices. Therefore, it is desirable to develop techniques and processes suitable for the fabrication of both 3C and 6H SiC devices.

Recent research demonstrates that the orientation of a particular atomic plane, the (0001) plane, relative to the wafer-growth surface is a factor that determines whether a 3C or 6H film will grow on the wafer. If a wafer is cut from a 6H boule such that the angle between the (0001) plane and the surface of the wafer (hereafter called the "tilt angle") is less than 1°, then the 3C structure will form on that wafer. In this case, the 3C film will have a fairly high defect density. However, if the tilt angle is

greater than about 1.5°, 6H will form during CVD.

The recently developed CVD process involves the use of 6H SiC wafers with tilt angles of about 3° to produce 6H films on the 6H wafers. The CVD process takes place in a water-cooled quartz chamber with a carrier gas of H_2 flowing at atmospheric pressure. As shown in the figure, the 6H wafers are supported and heated by an SiC-coated radio-frequency-heated graphite susceptor.

Prior to growth, the wafers are subjected to a 2-minute HCl etch at a temperature of 1,200 °C to remove residual contamination and damage caused by polishing. The temperature of the wafers is then raised to approximately 1,450 °C, and silane and propane are added to the carrier gas to start the growth of SiC film. Typically, a rate of growth of 4 μm/h is achieved with a carrier flow of 3 L/min, with silane at a concentration of 300 parts per million (ppm), and with propane at a concentration of 150 ppm.

The addition of small amounts of dopant materials (1 to 50 ppm) during growth yields films with desired electronic properties. For example, nitrogen or trimethylaluminum produces n-doped or p-doped films, respectively. In this manner, a variety of device structures can be produced.

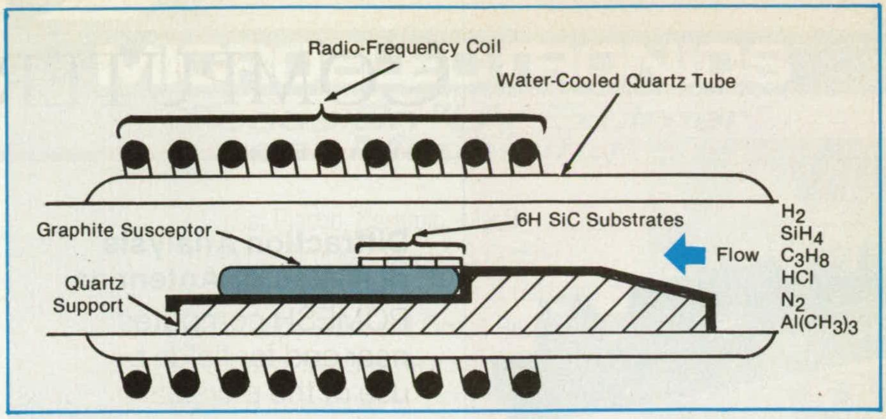
A typical 4-μm-thick 6H film was found to be smooth and nearly featureless when viewed with Nomarski optical microscopy. Upon examination by transmission electron microscopy and low-temperature photoluminescence, 6H films were found to be of semiconductor quality.

Further development is required for specific devices. For high-temperature applications, metalization and packaging processes are required. Some potential high-temperature applications include sensors and control electronics for advanced turbine engines and automobile engines, power electronics for electromechanical actuators for advanced aircraft and for space power systems, and equipment to be used in the drilling of deep wells. High-frequency applications include communication systems, high-speed computers, and microwave power transistors. High-radiation applications include sensors and controls for nuclear reactors.

This work was done by J. Anthony Powell, David J. Larkin, and Lawrence G. Matus of **Lewis Research Center** *and Jeremy B. Petit of Sverdrup Technology, Inc. Further information may be found in NASA TM-103655 [N-91-14850], "Silicon Carbide, a Semiconductor for Space Power Electronics."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

LEW-15377



Chemical Vapor Deposition of SiC is performed in a water-cooled quartz tube, with radio-frequency heating of the substrates.

COMPUTER PROGRAMS

Diffraction Analysis of Reflector Antennas

POMESH computes near and far fields by use of the physical-optics approximation.

POMESH is a computer program capable of predicting the performance of reflector antennas. It calculates both far-field patterns and gains by use of the physical-optics approximation of the equivalent surface currents.

POMESH is intended primarily for relatively small reflectors. It is useful in situations in which the surfaces are described by irregular data that must be interpolated and in which the surface derivatives are not known. It is flexible and robust. It also calculates near fields and is therefore quite useful for subreflector computations.

The program is constructed in a highly modular form so that it can be adapted readily to perform tasks other than the one that is explicitly described here. Inasmuch as the computationally intensive portions of the POMESH algorithm are simple loops, the program can be adapted easily to take advantage of vector processor and parallel architectures.

In POMESH, the reflector is represented as a piecewise planar surface that comprises triangular regions known as facets. A uniform PO current is assumed to exist on each triangular facet. Then, the PO integral on a facet is approximated by the product of the value of the PO current at the center and the area of the triangle. In this way, the PO integral over the reflector surface is reduced to a sum of the contributions from all the triangular facets.

The source horn, or feed, that illuminates the subreflector is approximated by a linear combination of plane patterns. POMESH contains three polarization-pattern definitions for the feed: a linear x-polarized element, a linear y-polarized element, and a circularly polarized element. If a more general feed pattern is required, it is a simple matter to replace the subroutine that implements the pattern definitions.

POMESH obtains information necessary to specify the coordinate systems, location of other data files, and parameters of the desired calculation from a data file provided by the user. A numerical description of the principal-plane patterns of the source horn must also be provided. The program is supplied with an analytically defined paraboloidal reflector surface. However, it is a simple matter to replace this paraboloid with a reflector surface defined by the user. Output is given in the form of a data stream to the terminal, a summary of the parameters used in the computation and some sample results in a file, and a data file of the results of the pattern calculations suitable for plotting.

POMESH is written in FORTRAN 77 for execution on CRAY-series computers running UNICOS. With minor modifications, it has also been successfully implemented on a Sun4-series computer running SunOS, a DEC VAX-series computer running VMS, and an IBM PC-series computer running OS/2. It requires 2.5 Mb of random-access memory (RAM) under SunOS 4.1.1, 2.5 Mb of RAM under VMS 5-4.3, and 2.5 Mb of RAM under OS/2. The OS/2 version requires the Lahey F77L compiler. The standard distribution medium for this program is one 5.25-in. (13.34-cm), 360K diskette in MS-DOS format. It is also available on a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format and a 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape in DEC VAX FILES-11 format. POMESH was developed in 1989 and is a copyrighted work with all copyright vested in NASA.

CRAY and UNICOS are registered trademarks of Cray Research, Inc. SunOS and Sun4 are trademarks of Sun Microsystems, Inc. DEC, DEC FILES-11, VAX, and VMS are trademarks of Digital Equipment Corp. IBM PC and OS/2 are registered trademarks of International Business Machines Corp. Inc. UNIX is a registered trademark of AT&T Bell Laboratories.

This program was written by Richard E. Hodges and William A. Imbriale of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 103*** *on the TSP Request Card. NPO-18807*

Software for Computing Image Ratios

RATIO_TOOL assists in analyses of multispectral images.

In some geological studies, spectral data are analyzed in order to gain information on surface materials. RATIO_TOOL is an interactive computer program for viewing and analyzing large sets of multispectral image data that have been created by an imaging spectrometer.

While the standard approach to classification of multispectral data is to match the spectrum for each input pixel against a library of known mineral spectra, RATIO_TOOL uses ratios between intensities in different spectral bands in order to spot significant areas of interest within a multispectral image. Each image band can be viewed iteratively, or a selected image band of the set of data can be requested and displayed. When the image ratios are computed, the result is displayed as a grayscale image.

At this point, a histogram option helps in viewing the distribution of values. A thresholding option can then be used to segment the ratio-image result into two to four classes. The segmented image is then color-coded to indicate threshold classes and displayed alongside the grayscale image.

RATIO_TOOL is written in C Language for Sun-series computers running SunOS 4.0 and later. It requires the XView toolkit software and the OpenWindows window-manager (version 2.0 or 3.0) software. The XView toolkit software is distributed with OpenWindows. A color monitor is also required. The standard distribution medium for RATIO_TOOL is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. An electronic copy of the documentation is included on the program medium. RATIO_TOOL was developed in 1992 and is a copyrighted work with all copyright vested in NASA.

Sun, SunOS, and OpenWindows are trademarks of Sun Microsystems, Inc. UNIX is a registered trademark of AT&T Bell Laboratories.

This program was written by Gigi L. Yates of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 51*** *on the TSP Request Card. NPO-18770*

Particle-Displacement Tracking in Particle-Image Velocimetry

Particle images are processed rapidly and automatically into velocity-vector maps.

Lewis Research Center, Cleveland, Ohio

Particle-displacement tracking is an all-electronic processing technique for use in particle-image velocimetry. In particle-image velocimetry, a flow is seeded sparsely with small particles, the flow is illuminated by a sheet of laser light in the plane in which velocity is to be measured, images of the particles are recorded at regular intervals, and the data from the sequence of images are processed into maps of velocity vectors.

Unlike some prior partly photographic techniques used in particle-image velocimetry, this one requires no processing of photographic plates. Unlike some partly or entirely electronic prior techniques, this technique requires no tedious visual recognition and manual designation of large numbers of image features for subsequent processing. Instead, particle-displacement tracking requires little or no interruption by a technician and is an order of magnitude faster than any of the prior techniques.

Particle-displacement tracking evolved from the vector-scanning technique, described previously in *NASA Tech Briefs*, in which a velocity-vector map of the flow field is generated from a five-exposure sequence of preprocessed single-exposure images recorded at equal intervals of time, ΔT (see Figure 1). Each preprocessed image consists of single-pixel dots at the centroids of the particles, and each single-exposure centroid dot is time-coded by making the dots from each exposure twice as bright as those of the preceding exposure in the sequence.

The particle-displacement-tracking algorithm scans the time-coded image, noting the locations of all pixels of initial brightness: these represent the initial locations of the particles. Within a specified circular region surrounding each initial location, a search is conducted for pixels of twice the initial brightness: these represent candidate locations for the position of the particle at ΔT after the initial exposure. The distance and direction from the initial location to each candidates second location are computed and used to project where the particle would be at $2\Delta T$, $3\Delta T$, and $4\Delta T$ after the initial exposure if it were moving at constant velocity. If pixels of 2^2, 2^3, and 2^4 times the initial brightness, respectively, are found within small search regions that surround these projected locations (see Figure 2), then a complete record of the movement of the

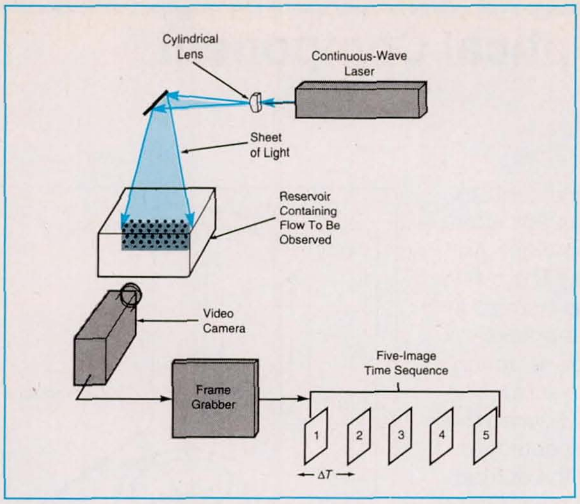


Figure 1. **Five Video Images** of illuminated particles entrained in a flow are recorded at equal intervals ΔT.

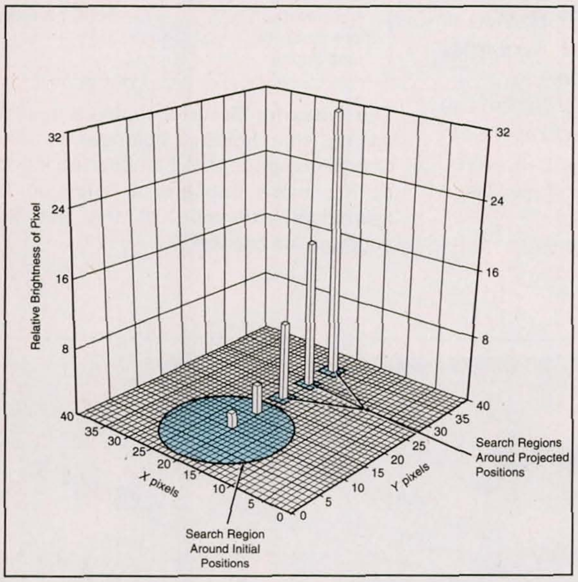


Figure 2. The **Sequence of Five Pixels** that constitutes the record of the motion of each particle is sought by the particle-displacement algorithm. Particle-centroid pixels are time-coded by brightness.

particle is deemed to have been found, and the velocity of the particle is computed as ($\frac{1}{4\Delta T}$) x(the displacement vector between the initial and final positions).

The method works best at low velocities. A frame grabber acquires the sequence of five images. The interval ΔT between images is chosen to suit the velocity range of interest, and can be any integral multiple of the standard video field interval of 1/650 second. The centroids of the particles are estimated by a simple boundary-following subalgorithm. The initial and particle-displacement processing can be done on a personal computer; in an early application, an image was processed on a personal computer based on an 80386 microprocessor, yielding 1,100 vectors in 110 seconds.

This work was done by Mark P. Wernet of **Lewis Research Center**. *Further information may be found in NASA TM-103288 [N91-10271], "Particle Displacement Tracking for PIV."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-15393.

Indexing Mount for Rotation of Optical Component

A ball detent maintains settings at preset angles.

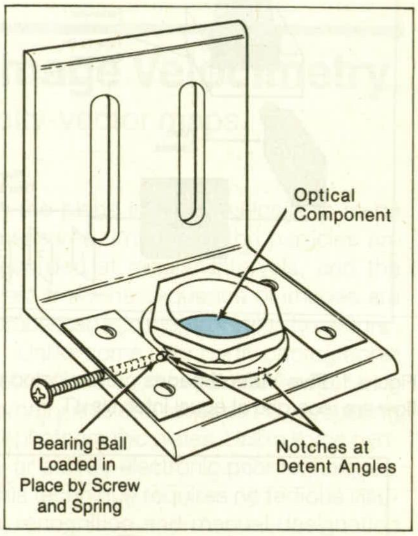
Langley Research Center, Hampton, Virginia

An indexing mount for a polarizer, wave plate, birefringent plate, or other optical component facilitates the rotation of the component to one or more preset angles. Previously, the component often did not have an optical mount with roll adjustment; that is, angular adjustment around an axis collinear with the direction of propagation of the optical beam. As such, much effort was consumed by having to rotate the optic and realign it on a regular basis. Now, with the help of the indexing mount, time-consuming and tedious angular adjustment are unnecessary: the component can be turned quickly and easily, by hand or by use of a wrench, to preset angular positions that are maintained by a simple ball-detent mechanism.

The optical component is placed in a $1\frac{15}{16}$-in. (49.2-mm) hexagonal nut, into which a 1-in. (2.54-cm) aperture has been machined. The nut includes a cylindrical extension that contains notches at the prescribed detent angles. (The notches would be 90° apart for a polarizer, for example, or 45° apart for a half-wave plate.) The cylindrical extension of the nut is inserted in a mating circular hole in the bracket. A ball bearing is secured by a spring, which in turn is backed by a screw. The ball bearing engages a notch when the nut is rotated to one of the detent angles (see figure). To rotate the component a fixed amount to the next detent angle, the user simply turns the nut until the bearing ball engages the next notch.

This work was done by Donald J. Reichle, Jr., and Norman P. Barnes of **Langley Research Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 10]. Refer to LAR-14772.



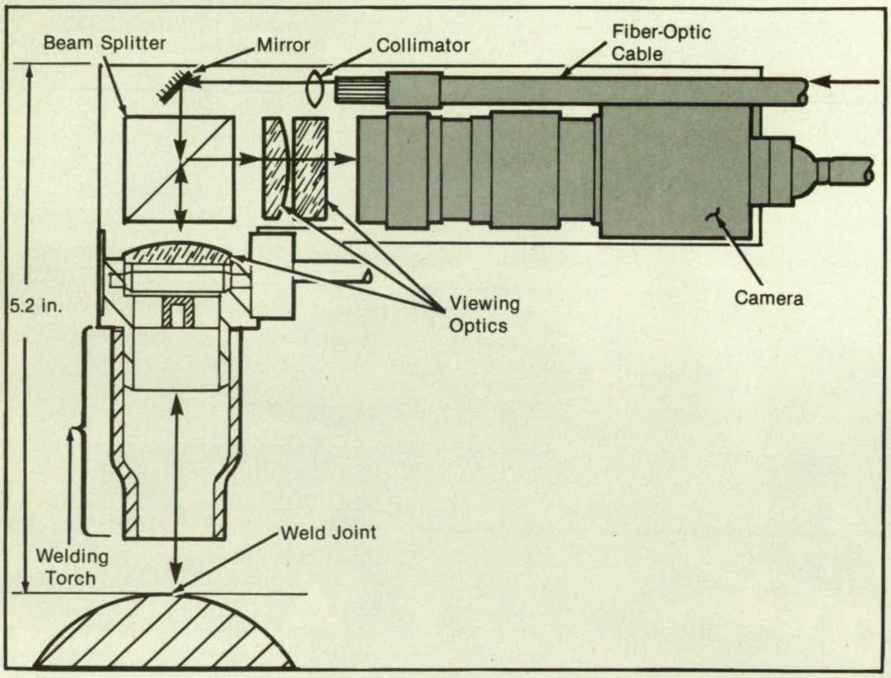
The **Indexing Mount** includes a hexagonal nut that holds a polarizer or other optical component. A ball bearing loaded by the screw engages a notch on the cylindrical extension of the nut that engages the bracket.

Auxiliary Illumination for Viewing Along a Welding Torch

Light from an external source augments or substitutes for light from the welding arc.

Marshall Space Flight Center, Alabama

An auxiliary optical subsystem provides additional illumination for a through-the-torch vision system of the type used in automated or semiautomated arc welding. The additional illumination is needed when light from the welding arc is not available (for example, during a practice run). Ambient light alone is not sufficient to locate a weld joint through the vision system because the optical path of the system is partly blocked by the filters that are needed to reduce the intense arc light to acceptable levels when the torch is operating. The additional illumination can also be useful during operation of the torch to view parts that are in shadows cast by the arc light.



An optical-fiber cable is attached perpendicular to the axis of the welding torch and parallel to the vision-system optics (see figure). The optical fibers carry light from a lamp and project it on a collimator and a mirror, which bends the collimated beam 90°. The beam passes through a beam splitter and enters the torch cup along the optical path of the vision system. The beam thus illuminates the workpiece. The optical-fiber cable and the lamp are remote from the welding arc and therefore unaffected by its heat and vapors. The cable easily fits in the torch body and adds nothing to its bulk.

This work was done by Jeffrey L. Gilbert and David A. Gutow of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 3*** *on the TSP Request Card.*

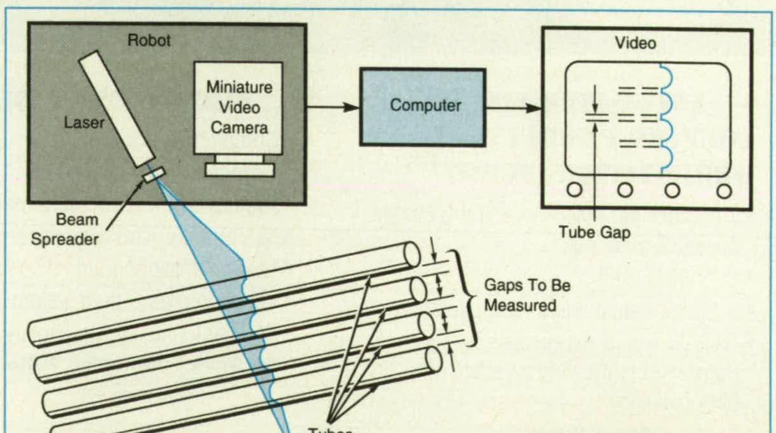
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 10]. Refer to MFS-29879

Robotic Tube-Gap Inspector

A robotic vision system would measure small gaps between nearly parallel tubes.

Marshall Space Flight Center, Alabama

A proposed robotic inspection system would measure the gaps between tubes mounted side by side. The system would include a miniature video camera mounted on a robot end effector. The robot would scan the nearly parallel tubes while the tubes were illuminated with a spread laser beam (see figure). The image of the illuminated tubes would be processed in real time by a dedicated computer, using specially developed algorithms. In the



The **Robot-Held Video Camera** would examine closely spaced tubes while the computer determined the gaps between the tubes. The video monitor would simultaneously display the data on the gaps.

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original intended application, the system would be used to ensure that a gap of 0.003 in. (76 μm) is maintained — the separation necessary for a brazed fillet between tubes in a rocket-nozzle heat exchanger.

A proof-of-concept demonstration showed that it is possible to detect the edges of the tubes in the image. However, the demonstration also showed that illumination had to be developed further to enhance the image.

The information on the gaps between the tubes would be stored in the computer and on videotape. The information could be retrieved subsequently to identify gaps that are too wide or too narrow. Technicians could then correct the gaps to ensure a braze of acceptable quality.

This work was done by Jeffrey L. Gilbert, David A. Gutow, and John E. Maslakowski of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29916

Tantalum/Copper X-Ray Targets

Plasma spraying enables fabrication of lightweight, high-performance targets.

Lewis Research Center, Cleveland, Ohio

In partial response to a need for a lightweight x-ray system that would offer improved performance and would be especially suitable for making three-dimensional images of the heart, the Technology-Utilization Office of Lewis Research Center developed a unique solution to the subsidiary problem of the fabrication of an x-ray target. An improved x-ray target would be a critical component of such an x-ray system.

For light weight and high efficiency, it is desirable to have a tantalum target face joined intimately to a highly thermally conductive backplate, in this case copper. The ability to remove heat from the target face is critical and depends, in turn, on the bonding of the tantalum and copper, which are widely dissimilar metals. Several attempts were made, and numerous ideas were evaluated. Standard joining approaches (e.g., fusion) were not adequate to solve the problem.

The problem was solved by use of NASA plasma-spraying technology. Power settings, atmosphere-control settings, the rate of deposition, and other spraying parameters were developed. Thin coats of tantalum were successfully deposited on copper targets. The targets performed successfully in tests and satisfied all criteria expressed in terms of critical parameters. Thus, it appears that plasma spraying will significantly reduce the projected costs of the fabrication of targets and will contribute to the development of an improved, long-lived, lightweight x-ray system.

This work was done by William J. Waters of Waters & Associates and Brian Edmonds of **Lewis Research Center**. *No further documentation is available.*
LEW-15516

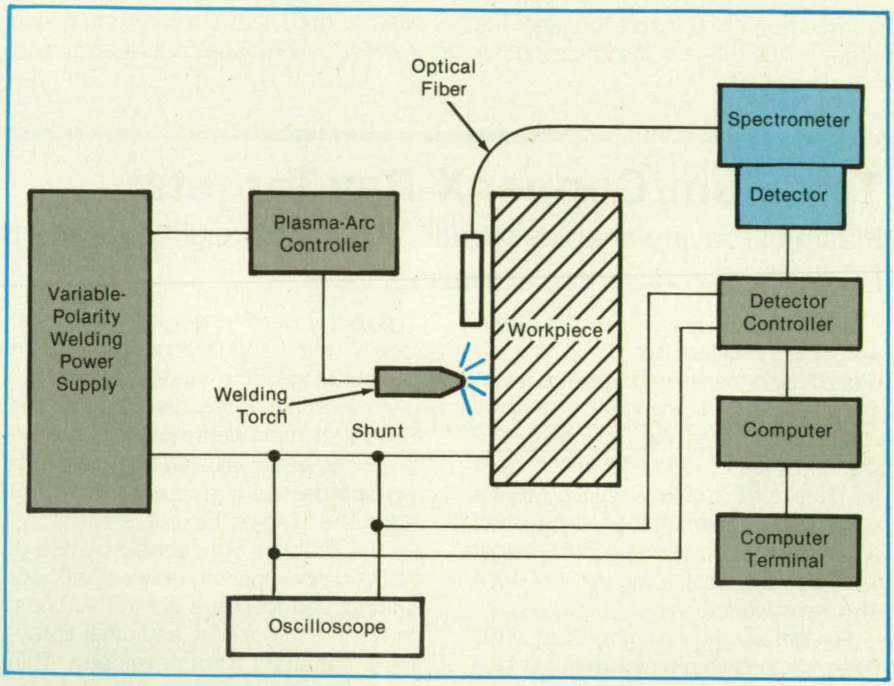
Measuring Weld Parameters by Spectroscopy

Composition, temperature, and penetration of the arc can be measured spectroscopically.

Marshall Space Flight Center, Alabama

An optical-emission spectrometric apparatus can be used to monitor variable-polarity plasma arc welding of aluminum alloys. For example, it can be set up to detect the presence of a "keyhole" — full penetration of a weld. A spectrometer of this type could be incorporated into a control system to ensure the quality of the weld because in a keyhole, the arc fully penetrates the weld joint and impurities are flushed out. The apparatus helps further to ensure high quality of the weld by monitoring such contaminants as oxygen and hydrogen in the shield gas, detecting inadequate flow of the shield gas, and sensing changes in the temperature of the arc with changes in the arc current and voltage.

One end of a quartz optical fiber is positioned near the torch (see figure). The fiber moves with the torch, and its field of view covers the entire arc except the part hidden inside the shield-gas cup. The other end of the fiber feeds the light from the arc to a grating spectrometer equipped with a diode-array detector. A multichannel spectrometric analyzer processes the signals from the detector, producing an output in 33 ms. The spectral resolution and wavelength range can be varied by changing the grating and grating angle.



Light From the Welding Arc is fed via an optical fiber to a spectrometer. The spectrum of the light can be used to determine the concentrations of contaminants and the temperature.

In a test of this spectrometric apparatus, it was found that the intensities of spectral features characteristic of hydrogen, which was deliberately introduced as a contaminant into the argon feed gas, decreased sharply when the workpiece was completely penetrated by the plasma stream. Thus, emission from hydrogen (measured by the spectrometer at a wavelength of 656 nm) can be monitored continuously, and the rate of flow of plasma can be increased or the speed of the torch decreased to keep the emission from hydrogen at a low level.

Similarly, the inert-gas shield (usually argon) can be monitored to ensure that it does not contain hydrogen, oxygen, and other contaminants. This is particularly important because shield-gas contaminants become disproportionately concentrated in the plasma arc and, therefore, in the weld bead.

A high concentration of contaminant(s) indicates that the rate of flow of shield gas is too low to ensure an inert blanket around the arc. Spectrometric determination of concentrations of contaminants can be used to control the flow of shielding gas to ensure that there is just enough to provide adequate shielding, and not so much as to waste the gas.

The apparatus measures temperature

by measuring the ratio between the intensity of the 696-nm argon line in the plasma and the intensity of the background radiation. This ratio increases with temperature, and thus might be used to regulate the arc current and voltage to provide a constant welding temperature.

This work was done by Arthur Nunes of **Marshall Space Flight Center** *and John C. McClure, Richard E. Marques, and Luis F. Martinez of the University of Texas, El Paso. For further information,* ***write in 9*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 10]. Refer to MFS-26206

Automated Alignment and Inspection of Duct Welds

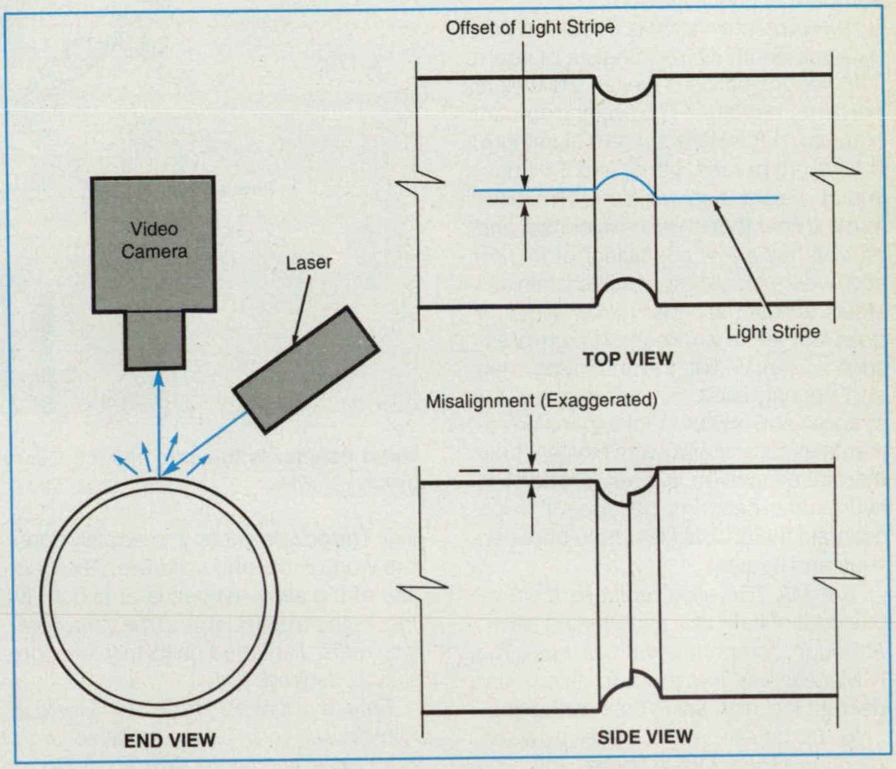
A system is being developed to replace slow and inaccurate manual techniques.

Marshall Space Flight Center, Alabama

A machine vision system is being developed for use in (1) aligning the ends of two round ducts before welding the ends together and (2) inspecting the welded ducts for alignment after welding. Previously, technicians measured thicknesses by use of micrometers and aligned ducts by sight; the procedure was slow and was inaccurate and inconsistent because it involved subjective judgments by the technicians. The system will make consistent, objective measurements quickly. Therefore, it is expected to improve the quality and reliability of welds, reduce the need for rework, and reduce alignment and inspection time, thereby reducing the cost of manufacture.

Before welding begins, the system measures the thickness and the out-of-roundness of the wall of each duct. During this measurement, a video camera that is part of the system views the end of each duct as the duct is rotated. The system records the thickness all the way around the circumference of the duct and simultaneously records data on the radius of the duct, compiling a complete set of data on the variation of these parameters for each duct. When the ends of two ducts are to be welded together, the system first aids in rough alignment of the ends: A technician or robot can use the thickness and out-of-roundness data to match adjacent sections as closely as possible with respect to wall thickness and ellipticity.

Next, the system is used to perform a fine alignment. A laser traces a longitudinal stripe of light across the interface between the two ducts to be welded (see figure). A video camera views the stripe; misalignment appears in the image as a lateral shift of the stripe from one duct to the other. An image processor calculates the amount of misalignment, which can be used by a technician to align the ducts manually or by a control computer to generate command signals for a robot that performs the alignment. This procedure is repeated at several locations on the circumference. Each measurement takes less than 1 s.



Misalignment Between Ducts Appears as an offset in the stripe of light traced by a laser beam.

The resolution of the measurements is a function of the number of pixels in the focal-plane array of photodetectors in the video cameras, quality and settings of the camera lens, and the viewing geometry. The accuracy of an experimental version of the system exceeds the requirements for welding in the original application; it measures misalignments ranging from 0.5 to 120 mils (0.013 to 3 mm) within 3 percent.

After the sections have been welded together, they are again scanned with a stripe of light. If the warping and distortion introduced by the welding process have caused misalignment, the stripe will be offset from one duct to the other. Previously, a plaster cast was made of the weld joint to check for misalignment — a cumbersome and inaccurate procedure.

It is expected that the fully developed system will be rolled around a shop floor on a cart. It will include a personal computer with a frame-grabber/image-processor circuit board plus a laser and camera with optical-fiber cables connected to a fixture, part of which could be clamped on a duct. The fixture, under computer control, would move the cables along and around the duct so that the laser and camera could scan it.

This work was done by George S. Cross of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 55*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 10]. Refer to MFS-29914

Coating a Bearing With Oxygen-Compatible Material

Laser powder injection would produce a wear-resistant, dimensionally stable coat.

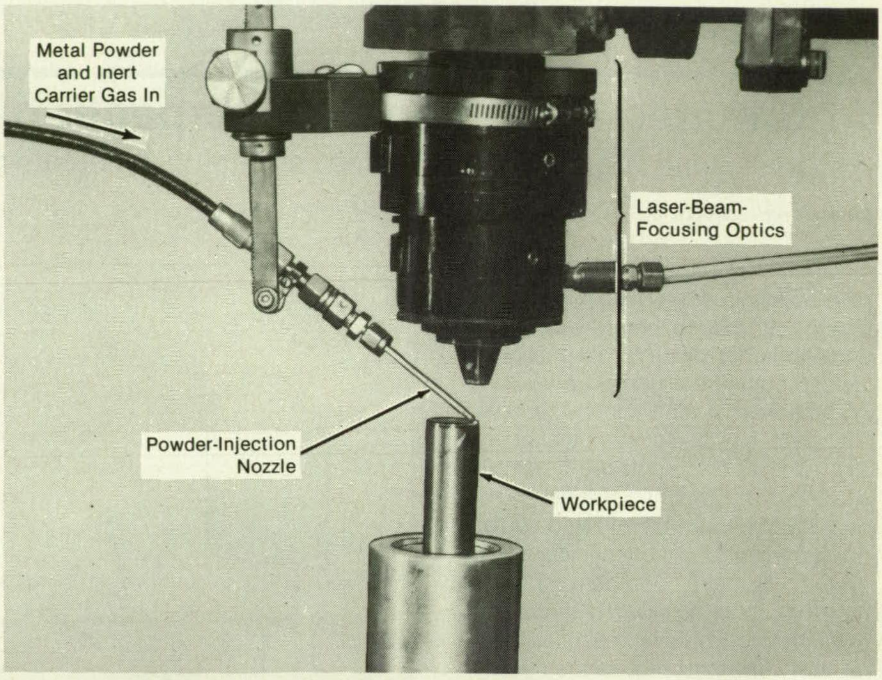
Marshall Space Flight Center, Alabama

A laser powder-injection process is being developed to coat the contact surfaces of a shaft and hydrostatic bearing with an alloy that protects against attack by liquid or gaseous oxygen. The protective coat is needed because the bearing in question is part of a liquid-oxygen turbopump and is exposed to liquid and gaseous oxygen at pressures sufficient to cause ignition.

The protective alloy is INCO MA 754 (or equivalent), which consists of about 77.6 weight percent nickel, 20 weight percent chromium, 0.5 weight percent titanium, 0.3 weight percent aluminum, 0.6 weight percent yttria, and 1.0 (maximum) weight percent iron. This alloy forms a coat that is uniform, dense, and hard. It has a low coefficient of friction and wears negligibly. Unlike stainless steels and some other nickel alloys, it does not ignite and burn in high-pressure oxygen. With it, the underlying shaft and bearing alloy can be selected for strength and low thermal expansion rather than compatibility with oxygen. Low thermal expansion is a key property in hydrostatic bearings because it helps maintain the critical clearance between shaft and bearing.

The MA 754 alloy replaces a previous coat of K-Monel and sterling silver. Although compatible with oxygen, the K-Monel/silver coat tends to deform under rubbing, increasing the bearing gap.

In the developmental laser powder-injection process (see figure), the alloy powder is metered from a hopper into the beam of an yttrium aluminum garnet laser at a defocused hot zone just above the workpiece (the shaft or bearing). The powder melts, immediately coats the workpiece, and solidifies. The density of the alloy deposit is at almost its theoretical maximum, and the yttria component is dispersed uniformly throughout, as desired.



Metal Powder Is Injected into the laser beam, which melts the powder onto the workpiece.

This work was done by Merle E. Funkhouser and William J. Dalzell, Jr., of Pratt and Whitney for **Marshall Space Flight Center**. *For further information,* ***write in 93*** *on the TSP Request Card.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C 2457(f)], to United Technologies. Inquiries concerning licenses for its commercial development should be addressed to

Herbert W. Mylius
United Technologies
P.O. Box 109600
West Palm Beach, FL 33410

Refer to MFS-28687, volume and number of this NASA Tech Briefs *issue, and the page number.*

Monitoring Weld Penetration Optically From Within Torch

The monitoring components would cause less mechanical interference and would remain aligned.

Marshall Space Flight Center, Alabama

A photodetector or an optical fiber leading to a photodetector would be mounted inside a gas/tungsten arc welding torch (see figure) to monitor arc light reflected from the oscillating surface of the weld pool, according to a proposal. Heretofore, an optical detector was mounted outside the weld torch, resulting in a bulky configuration and consequent increased mechanical interference with various objects in the workspace. The external detector was sensitive to changes in the height and angle of the torch and had to be realigned to accommodate these changes. The external detector was also sensitive to high operating temperatures, high welding currents, and high welding voltages. The proposed optical monitoring components would preserve the compact profile of the welding torch, would be maintained in fixed aim at the weld-pool position at the end of the welding torch, and would be protected against bumping external objects by mounting it inside the welding torch.

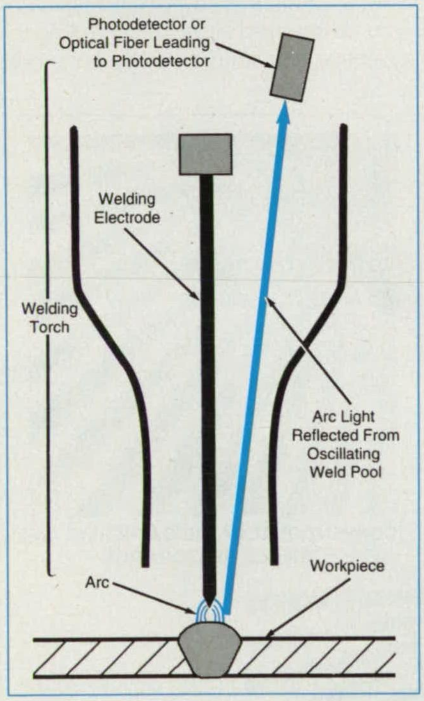
An optical monitor is used to measure oscillations of the weld pool because the frequency of these oscillations is approximately inversely proportional to the width of the back bead of the weld. It is necessary to monitor and control the width of the back bead because this width is a measure of the penetration of the weld

into the workpiece and it affects the quality of the finished weld.

The proposed photodetector mounted in the weld torch would be a robust military-grade photodiode. The output of this photodiode (or, alternatively, the output of an external photodiode fed from within the torch by an optical fiber) would be cleaned up and amplified, then processed to extract the frequency of vibration of the weld pool. This frequency could then be fed to a welding-control computer, which would adjust the welding current to maintain the desired width of the back bead.

This work was done by Matthew A. Smith, Jeffrey L. Gilbert, Deron L. Linsacum, and David A. Gutow of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 39*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 10]. Refer to MFS-29926.



At a **Fixed Vantage Point** within the torch, a photodiode would observe the weld pool, regardless of the angle or position of the torch.

MATHEMATICS AND INFORMATION SCIENCES

Multiresponse Imaging for Improved Resolution

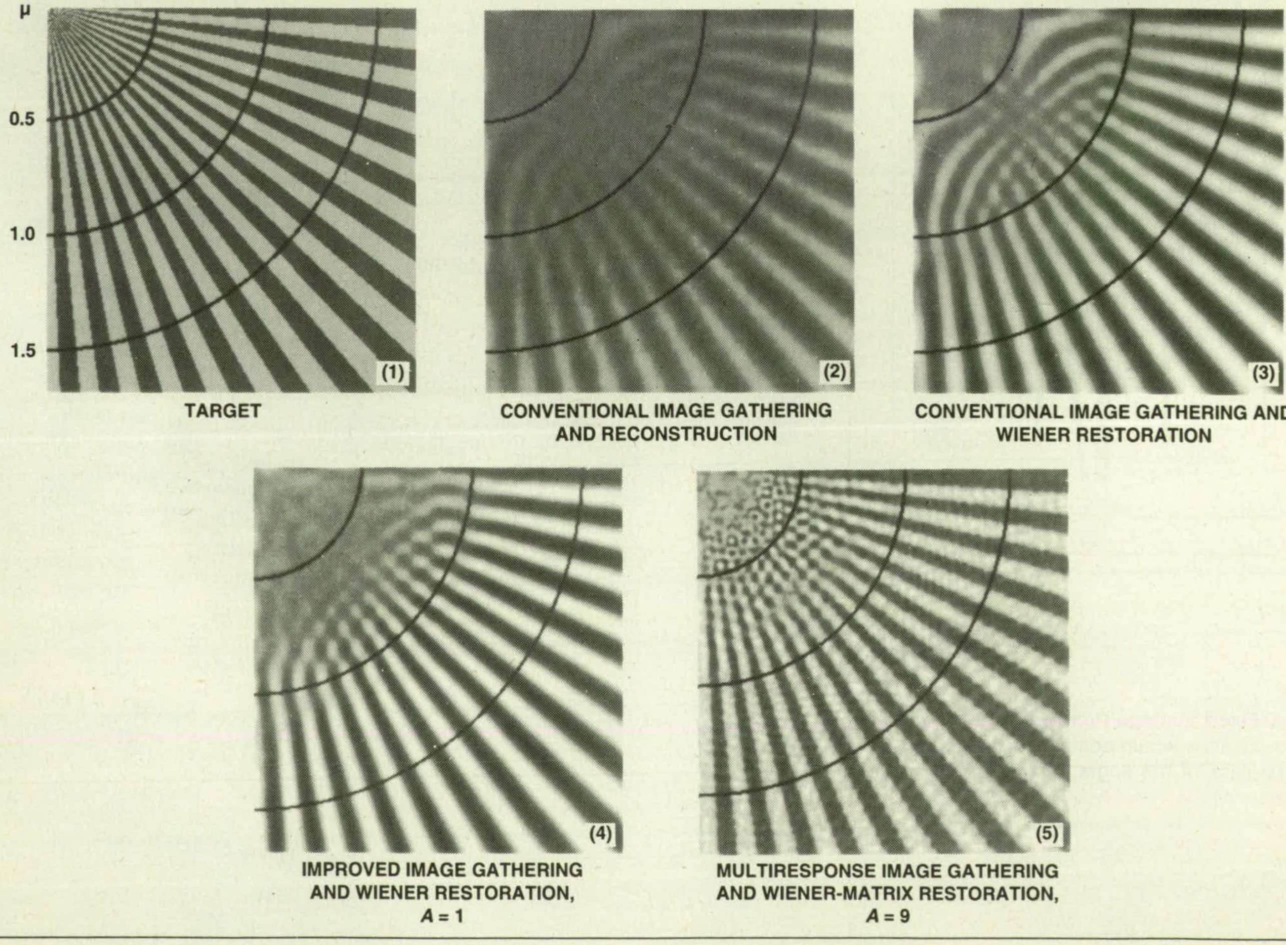
Images can be restored with a resolution finer than the sampling lattice.

Langley Research Center, Hampton, Virginia

The performance of conventional imaging is critically constrained by its sampling passband, optical response, and sensitivity. These constraints limit the resolution of the images to the sampling lattice of the photon-detection mechanism, and further degrade their quality by blurring, aliasing artifacts, colored noise, and ringing.

Multiresponse imaging overcomes the sampling-passband constraint and is critically constrained only by the optical response and sensitivity of the image-gathering device. This process consists of multiresponse image gathering and Wiener-matrix restoration. The image-gathering process acquires a sequence of images, each with a different optical response so that the within-passband and aliased signal components are weighted differently. The Wiener-matrix filter, in turn, unscrambles the within-passband and aliased frequency components of the undersampled signal and restores them up to the cutoff frequency of the optical response.

This multiresponse imaging process makes it possible to reassemble from $\mathcal{A}$ successive images a single image with an improved resolution that can approach $1/\sqrt{\mathcal{A}}$ times the sampling lattice of the photon-detection mechanism. The resolution that is actually attained depends on the optical responses and the sensitivity. The image-gathering devices include television cameras and charge-coupled-device imagers. The optical responses may be changed either by controlling the objective lens aperture or by using bire-



TARGET

CONVENTIONAL IMAGE GATHERING AND RECONSTRUCTION

CONVENTIONAL IMAGE GATHERING AND WIENER RESTORATION

IMPROVED IMAGE GATHERING AND WIENER RESTORATION, $A = 1$

MULTIRESPONSE IMAGE GATHERING AND WIENER-MATRIX RESTORATION, $A = 9$

fringent blur filters. When only a single image is acquired — i.e. $\mathcal{A} = 1$ — the image gathering and restoration produces an image that is limited in resolution to the sampling lattice of the photon-detection mechanism. However, this image is sharper and clearer than those obtained by conventional methods, because the filter accounts not only for the aliasing and blurring in the image-gathering device but also for the blurring and raster effects of the image-display device.

The figure presents the following:

- (1) A target of resolution wedges with a continuously varying width μ. When $\mu = 1$, the width is equal to that of the sampling lattice of the photon-detection mechanism.
- Images produced by conventional image gathering with either (2) reconstruction or (3) Wiener restoration. The reconstruction is impaired by the aliasing and blurring in the image-gathering process and by the blurring and raster effects in the image-display process. The restoration suppresses the blurring in the image-gathering process, but none of the other impairments.
- Images produced by the improved image gathering and Wiener restoration method, either for (4) $\mathcal{A} = 1$ or (5) $\mathcal{A} = 9$. The restoration for $\mathcal{A} = 1$ suppresses the aliasing and blurring in the image-gathering process and the blurring and raster effects in the image-display process. In addition, the restoration for $\mathcal{A} = 9$ unscrambles the within-passband and aliased frequency components for spatial detail approaching $\mu = 1/3$ times the sampling lattice.

This work was done by Carl L. Fales, Jr., and Friedrich O. Huck of **Langley Research Center**. *For further information, Write in 85 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 10]. Refer to LAR-14779.

Opaque Contact Lens for Tracking Motion of Eye

Marks on the lens are observed with a video camera.

Lyndon B. Johnson Space Center, Houston, Texas

An opaque contact lens facilitates measurements of the movements of an eye; particularly, torsional movements. The lens, which is marked with a pair of indices at a diameter of 0.5 mm, provides a stable, high-contrast reference for measurements of the angular position and velocity of the eye by use of video-image-analysis techniques. It is intended for use in experiments on the response of the eye to the vestibular balance mechanism.

The lens is made of polymethylmethacrylate (PMMA), the same material used in hard contact lenses for daily wear. It provides better reference marks than the naked eye does: in light-colored eyes, particularly, natural markings do not have sufficient contrast. The opacity of the lens also shields the eye from ambient light, so that the subject perceives darkness, as required for vestibular experiments.

The opaque hard lens replaces a translucent soft lens that was used previously. In comparison with the soft lens, the hard lens is more stable during blinking and other movements and thus maintains its index marks in a more nearly fixed position relative to the globe of the eye. The hard lens is fabricated on a cast impression of the eye; hence, its stability. It does not rely on contact with the cornea for its nonmoving fit; in fact, it arches slightly, with a small clearance over the cornea. Two tiny fenestrations admit tears to the cornea during blinks, to prevent anoxic stress and increase comfort. The lens rests easily on the white of the eye and can be worn for as long as four hours without causing undue corneal edema.

The first step in the fabrication process is to take an impression of the surface of the eye by use of a standard clinical procedure. A clear PMMA contact lens is made from the impression. After the transparent lens has been fitted satisfactorily to the wearer, an opaque PMMA duplicate is molded from it, polished, and inscribed with the index marks.

This work was done by James L. Zografos II and Charles R. Gibson of KRUG International for **Johnson Space Center**. *For more information,* ***write in 18*** *on the TSP Request Card. MSC-21901*

Apparatus Would Stain Microscope Slides

The device would operate semiautomatically, with little or no leakage.

Lyndon B. Johnson Space Center, Houston, Texas

The proposed apparatus shown in the figures would meter specific amounts of fluid out of containers at specific times to stain microscope slides. Intended specifically for the semiautomated staining of microbiological and hematological samples in microgravity, the leakproof apparatus could be used in other environments in which technicians have little time to allocate to staining procedures and/or exposure to toxic staining agents or to the micro-organisms to be stained may be hazardous. Because the apparatus could be adapted to perform almost any staining procedure and because it could accommodate multiple staining reagents, it could be very useful for small or remote clinical laboratories.

In the first step of operation, the technician would place a specimen containing the micro-organism(s) to be stained on the center of a microscope slide. The technician would place the slide in the staining chamber. Closing and securing the chamber cover would force the slide onto the O-ring, forming a small cavity between the surface of the slide and an inner surface of the chamber.

The technician would then select and initiate the appropriate test [e.g., Gram stain, Wright/Giemsa stain, acid-fast (DMSO-modified) stain, Loeffler's methylene blue stain] by pressing the appropriate key(s) on a keypad on the front of the apparatus. The technician would then be free to pursue other tasks, until the process is complete, at which time a "cycle complete" indicator would light up.

Upon selection and initiation of the test via the keypad, a microprocessor would cause servomotor A to rotate the circular plate until a male connector on a transfer tube mounted on the plate became aligned with a female connector on the appropriate one of several reagent containers. Servomotor B would then be activated to drive a subassembly that would include servomotor A, the circular plate, and the male connector toward the right (in the figure). This action would couple the male and female connectors. A specific amount of fluid would then be drawn from the reagent container, through the transfer tube, and into the staining chamber. The amount of fluid will correspond to the internal volume of the staining chamber, transfer tube, and connectors.

The coupling would remain during a preset time to expose the specimen adequately to the reagent. Servomotor B would again be activated in the opposite direction to decouple the connectors and stop the

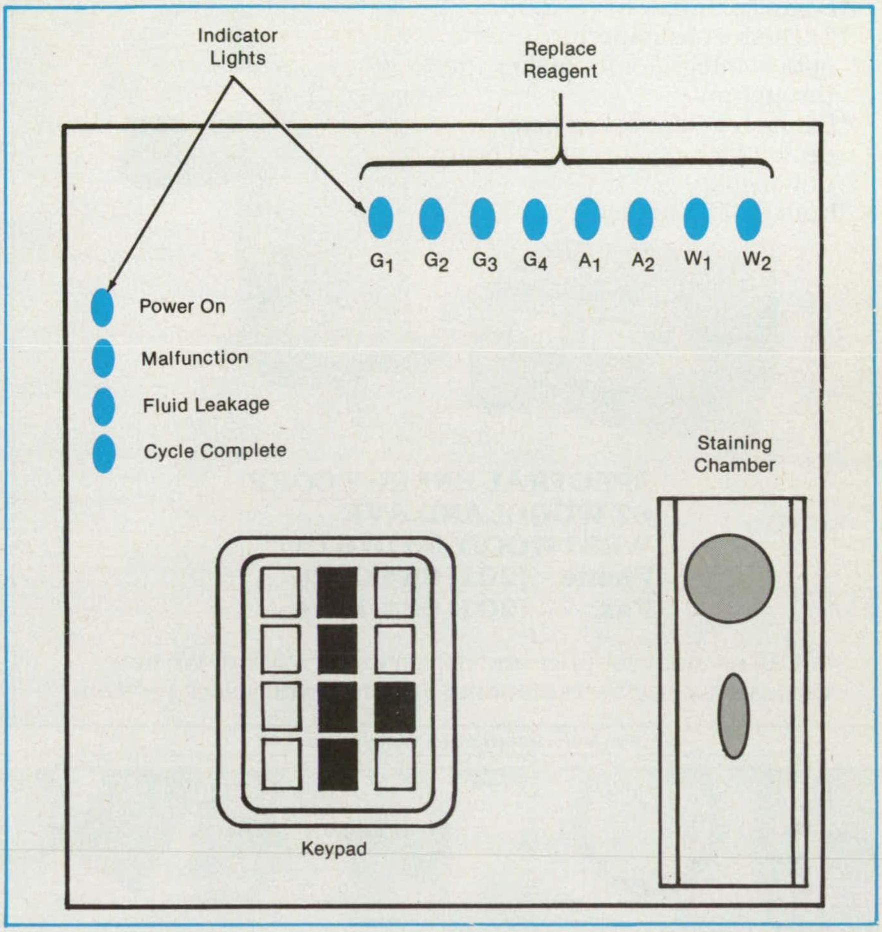


Figure 1. The **Front Panel** of the apparatus would hold the control buttons, indicator lights, and staining chamber.

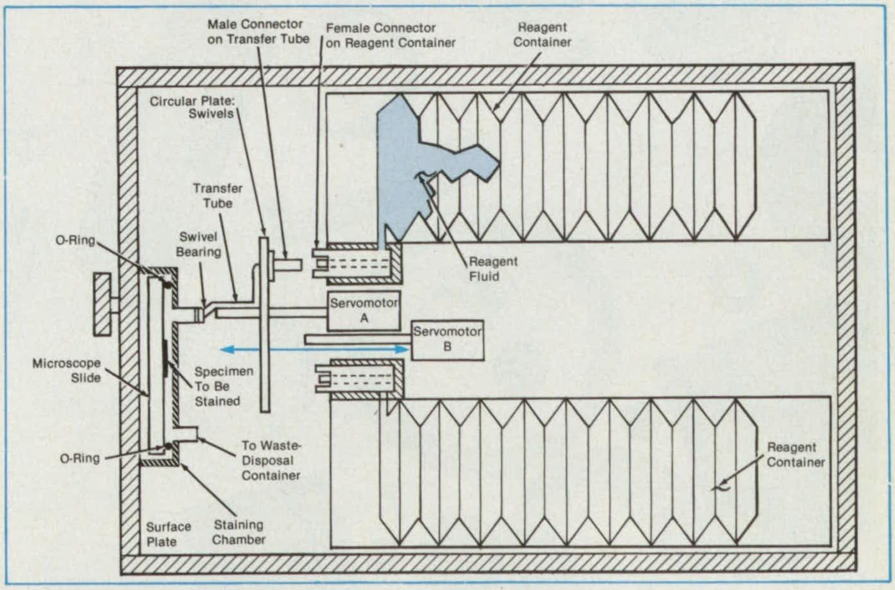


Figure 2. **The Interior Components** of the apparatus are illustrated schematically. The reagent containers would be bellows, each of which would be sprung to collapse to its shortest length and thereby squeeze fluid from inside itself.

transfer of reagent from the container. Servomotor A would then be activated to rotate the circular plate to the position for coupling to the next reagent container. In most cases, water stored in one of the reagent containers would be used to rinse each staining reagent from the slide prior to application of the associated counter-staining reagent.

This process of activating the appropriate servomotor, applying the reagent, applying the next reagent, etc., would continue until the process was complete. The circular plate would then return to its initial position, and the "cycle complete" indicator would signal that the slide may be removed from the chamber for visual analysis via microscope.

This work was done by James D. Breeding of McDonnell Douglas Corp. for **Johnson Space Center**. *For further information,* ***write in 12*** *on the TSP Request Card. MSC-21810*

Subpixel Resolution in Depth Perceived Via 3-D Television

When viewing stereoscopic television, trained observers were found to utilize subpixel brightness cues.

Trained human observers have been found to perceive depths at subpixel resolutions in stereoscopic television images. This finding has significance for remote stereoscopic monitoring, especially during precise maneuvers of remotely controlled manipulators. Of course, it also has significance for research in the processing of visual information by the human brain.

The report describes an experiment in which two black vertical bars on a featureless white background were placed near the intersection of the optical axes of two charge-coupled-device video cameras positioned to give stereoscopic views. The left bar was kept at the same position during all observations. The right bar was placed at one of nine different positions during each observation; one position was at the same distance from the cameras as that of the left bar, while four positions were closer and four were farther. The linear and angular dimensions of this viewing scheme were chosen so that the placement of the right bar at the various positions resulted in subpixel lateral displacements in the television images.

Each observer was instructed to look at the stereoscopic television images for as long a time as necessary, then decide whether the right bar was surely closer or farther than, probably closer or farther than, or equally as far as, the left bar. When the test was completed, each observer had made 120 observations at each location. The observers' responses were analyzed statistically.

The nominal pixel depth resolution of the particular viewing geometry was 5 mm. However, the observers' responses were characteristic of a depth resolution of 1 mm. The experimenters conjecture that the human vision system may attain the higher subpixel depth resolution by exploiting a built-in edge-enhancement function that sharpens the percept of a blurred image. The edge-enhancement function may interpret changes in the brightnesses of adjacent pixels in terms of subpixel displacements, across those pixels, of edges between bright and dark areas. In stereoscopic television, small changes in depth would result in such edge displacements and corresponding changes in brightness. Apparently, the human vision system can be trained to interpret those changes in terms of changes in depth.

This work was done by Daniel B. Diner, Marika von Sydow, and Derek H. Fender of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Sub-Pixel Resolution in 3-D Television for Teleoperation,"* ***write in 30*** *on the TSP Request Card. NPO-18661*

Microwave Holography Helps Improve Performance of Large Antennas

Refinements are added to the basic inverse-Fourier-transform technique.

A report describes the use of microwave holography and related techniques of measurement and computation for diagnostics, analysis, and performance improvement of large microwave reflector antennas over all operating frequencies (wide-bandwidth improvement). The microwave holographic technique is based on the Fourier-transform relationship between the complex (amplitude and phase) far-field radiation pattern of the antenna at small angles off the boresight axis, and the complex electromagnetic antenna aperture field distribution, as a function of position, which can be expressed in terms of an equivalent surface current density.

By the use of an inverse fast Fourier transform, the aperture phase error (the local difference between the actual phase of the aperture field and the phase that would be produced by the nominal perfect reflector antenna) is extracted from the far-field measurements. The "effective" residual surface error map is derived by invoking geometrical optics ray tracing, and removing the aperture phase due to pointing and subreflector position errors. Panel adjustments based on the "effective" map will improve the antenna performance at a single frequency (narrow-bandwidth improvement) due to frequency-dependent "effects" included in it. Many antennas, including the NASA Deep Space Network (DSN) antennas operate at several different frequencies and require wide bandwidth performance improvement. By removing the aperture feed phase function (computer predicted, using antenna diffraction analysis) and the struts' diffraction effects, a frequency independent map ("mechanical" map) is derived. Rigid body panel setting and screw adjustments listing derived from the "mechanical" map data, will improve the antenna performance over all operating frequencies.

In the application described in the report, the inverse fast Fourier transform is applied to the far-field measurements, revealing the amplitude aperture illumination, as usual; then additional crucial performance parameters are derived, which include panel alignments (rigid body), predicted surface after panel setting, screw adjustments listing, subreflector position correction, directivity at various frequencies, gravity distortion analysis utilizing low-order polynomial decomposition (for further design of gravity compensation by other components in the antenna relay), and separation of random from systematic error components.

The augmented microwave holography technique was applied to the newly constructed 34-m-diameter beam-waveguide antenna in the NASA/JPL DSN. The antenna performance was improved at all operating frequencies (wide-bandwidth improvement) by reducing the root-mean square displacement error of the reflector surface of 0.43 mm. At the Ka-band (32 GHz), the estimated improvement was 4.1 dB, resulting in an aperture efficiency of 52 percent (from the Cassegrain focus). The performance improvement was verified by efficiency measurements and additional holographic measurements.

This work was done by David J. Rochblatt of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "A Methodology for Diagnostics and Performance Improvement for Large Reflector Antennas Using Microwave Holography,"* ***write in 61*** *on the TSP Request Card. NPO-18712*

Organic Materials for Optical Switching

Equations predict properties of candidate materials.

A report presents the results of a theoretical study of nonlinear optical properties of organic materials. Such materials could be used in optical switching devices for computers and telecommunications, replacing electronic switches. Optical switching potentially offers extremely high information throughput in compact hardware.

Organic materials are attractive because the nonlinearities in their electric polarizabilities can be orders of magnitude greater than those of such commonly used inorganic materials as lithium niobate and potassium dihydrogen phosphate. Moreover, organic materials can be designed to have molecular combinations and structures that enhance their nonlinear dielectric and optical properties. For example, they should be transparent to the incident light at its fundamental frequency and its second or third harmonic, resistant to damage up to a high threshold level of incident light, and — for second-order nonlinear effects — have acentric crystal structures or molecular orientation.

The report presents equations that can be used to predict the molecular polarizabilities of organic molecules that could be incorporated into thin films. (Synthesis of thin films with interpenetrating lattices of electroactive molecules is the focus of much current work.) Calculations based on the equations can help material scientists screen the best candidate materials for optical-switching applications.

The equations were developed by taking the static-field approach to the prediction of the polarizabilities of organic molecules. In this approach, ground-state energies are calculated directly by a variational method in the presence of a dipolar static perturbing field. A computer code has been developed for calculating the second-order polarizabilities and applied to mono-, di-, and tri-substituted naphthalene, quinoline, and isoquinoline. At the time of submission of the report, the code was undergoing extension to enable it to calculate third-order polarizabilities.

This work was done by Beatriz H. Cardelino of Spelman College for **Marshall Space Flight Center**. *To obtain a copy of the report, "Nonlinear Optical Properties of Organic Materials: A Theoretical Study,"* ***write in 1*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 10]. Refer to MFS-27280.

Distributing Frequency and Time Signals on Optical Fibers

Recent developments have increased frequency and phase stability.

A paper reports on progress in the distribution of frequency and time reference signals over optical fibers. It describes current performance at frequencies of 100 MHz, 1 GHz, and 8.4 GHz. It describes transmitting and receiving equipment and discusses the tradeoff between cost and performance; for example, it describes a cheaper distribution system for use where the full stability of a hydrogen maser is not needed. The paper concludes with a discussion of likely future development and the effects of those developments on systems that use the distributed frequency reference signals.

In 1986, the paper notes, the Allan deviation (a measure of the differential

frequency instability) of a 14-km optical-fiber link at an averaging time of 1 second was four times worse than that of a hydrogen maser because of loss of signal over the long distance. Another source of instability was optical reflections from various components. If reflected light was allowed to enter the laser, it caused increased phase noise and amplitude noise. At that time, manufacturers attempted to reduce reflections from connectors and other components, but this practice proved inadequate for the distribution of reference frequency signals. Manufacturers then began to add integral optical isolators to their laser packages. Then they found ways to reduce reflections from surfaces inside the laser package.

Today, optical-fiber cable stabilizers reduce instabilities below the level achievable with passive means. The stabilizers can virtually eliminate diurnal variations in group delays in long analog optical-fiber links for either narrow-band reference signals or wide-band data signals.

Meanwhile, phase noise has been reduced steadily. The phase noise of a typical state-of-the-art optical-fiber distribution system is lower than that of any frequency standard now in use and approaches the phase noise of cryogenic frequency standards under development.

This work was done by George F. Lutes of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Status of Frequency and Timing Reference Signal Transmission by Fiber Optics,"* ***write in 35*** *on the TSP Request Card. NPO-18659*

Analysis of Noise in Optical Phase-Locked Loop

Effects of shot noise, modulation noise, and frequency noise are considered.

A report presents a theoretical and experimental analysis of noise in a coherent optical phase-locked loop (in which a frequency-stabilized laser is the local oscillator). The optical phase-locked loop is of a type that is being considered for use in heterodyne reception of binary pulse-position modulation at a data rate of 100 Kb/s in an optical communication system in which the transmitter would also include a frequency-stabilized laser.

In the theoretical part of the analysis, the loop is assumed to be disturbed by shot noise (an additive white Gaussian noise), modulation noise, and frequency noise. Originating as an irreducible minimum noise in the laser oscillator itself, the power spectral density of frequency noise is assumed to include a white-noise component, a $1/f$ component, and a $1/f^2$ component (where f is the deviation from the carrier frequency on which the loop is intended to lock). The transient and steady-state responses of the optical phase-locked loop are assumed to be governed by the transfer function of a loop filter; specifically, a perfect second-order loop transfer function of the form

$$(1 + \tau_2 s)/\tau_1 s$$

where τ_1 and τ_2 are characteristic times and s is the Laplace-transform complex frequency.

On the basis of the foregoing assumptions, closed-form equations for the contribution of the shot noise and of each component of frequency noise to the total phase-error variance of the optical phase-locked loop are derived. It is also shown that the contribution of modulation noise to the total phase-error variance occurs as a multiplicative factor (rather than an additive term) that depends only on the ratio between the loop bandwidth and the data rate. This multiplicative factor approaches 1 (that is, the effect of modulation noise becomes negligible) when the loop bandwidth is less than about ¼ of the data rate.

Phase-tracking experiments were performed on a laboratory version of the optical phase-locked loop. The local oscillator in these experiments was a 1.06-μm-wavelength neodymium:yttrium aluminum garnet laser, the frequency of which could be varied over a range of 30 GHz, with temperature tuning. Fast frequency tuning is achieved via a piezoelectric transducer that applied a stress to the laser cavity. Phase-error variances were measured in the experiments and were found to match closely those predicted by the equations. The results of the phase-locking experiment indicate that at a closed-loop bandwidth of 20 kHz, the phase-error variance is only 0.05 mrad^2.

This work was done by Moe Z. Win and Chien C. Chen of Caltech and Robert A. Scholtz of the University of Southern California for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Optical Phase-Locked Loop (OPLL) for Free-Space Laser Communications With Heterodyne Detection,"* ***write in 47*** *on the TSP Request Card. NPO-18638*

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Study of Laser-Induced Copolymerization

A theory of photoinitiation of copolymerization of styrene and maleic anhydride arises from experiments.

A report that describes experiments on the photopolymerization of a styrene/maleic anhydride copolymer has been published as part of the Laser Polymerization Program at NASA Langley Research Center. This report presents a basic study of the copolymerization of styrene and maleic anhydride under laser-induced initiation and polymerization. It helps to clarify different theories on such initiation and represents significant advances in the understanding of basic processes.

The advantage of using a laser to initiate polymerization is that it offers better control of the production of the initiating free radicals via control of the duration, intensity, and wavelength of the laser beam. An argon laser and a pulsed dye laser were used in the experiments.

The styrene/maleic anhydride copolymer system was chosen because polymerization in this system could be photoinitiated directly, without the use of photosensitizers, thereby avoiding chemical contamination by initiator residues. Styrene and maleic anhydride monomers form a regularly alternating copolymer over wide ranges of mixing ratios. This phenomenon has intrigued polymer chemists for many years, and the exact mechanisms for the initiation and propagation steps are still being debated. Most investigations have dealt with the process of propagation of thermally induced copolymerization; however, attention is now being turned toward photoinitiation.

In solution, styrene and maleic anhydride form charge-transfer complexes, also known as electron-donor/acceptor complexes. The formation of most of these complexes is detectable in the ultraviolet and visible absorption spectrum. In the experiments, the initiation step of the photopolymerization process in which styrene/maleic anhydride copolymer is formed was investigated at a wavelength of 365 nm, using an ultraviolet-and-visible spectrophotometer. The ultraviolet absorption measurements provide decisive evidence that the styrene/maleic anhydride charge-transfer complex is the sole absorbing species; however, the results of laser experiments in this study suggest that intermediate reactions lead to a monoradical initiating species. A mechanism for the photoinitiation step of the copolymerization process is proposed in the report.

This work was done by Gilda A. Miner and Willard E. Meador of **Langley Research Center** *and C. Ken Chang of Christopher Newport College. Further information may be found in NASA TM-4166 [N90-17810], "Initiation Precursors and Initiators in Laser-Induced Copolymerization of Styrene and Maleic Anhydride in Acetone."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LAR-14552

Investigation of Far-Field Diffraction

Some patterns that do not agree with theoretical predictions have been observed.

A report describes an experimental investigation of far-field diffraction by normally illuminated circular apertures with diameters of several wavelengths of the incident light. The purpose of the investigation was to determine whether Keller's "geometrical" theory of diffraction is valid for diffraction phenomena of this kind.

In each experiment, linearly polarized light at a wavelength of 0.6328 μm from a 35-mW He/Ne laser or unpolarized light at the same wavelength from a 15-mW laser was used to illuminate the chosen aperture at normal incidence. In some experiments, the laser beam was focused onto the aperture by a microscope objective lens. In other cases, the lens was not used; that is, the incident beam was collimated. The apertures were pinholes in stainless-steel foils, ranging from a diameter of about 1.3 μm in a sheet 1.7 μm thick to a diameter of about 5 μm in a sheet 6 μm thick. The laser beam was shuttered to control exposure time, and the diffraction patterns made by the forward-scattered light were recorded on photographic film. The films were placed at various distances from the aperture, ranging from 1.7 to 7.8 cm.

The diffraction patterns recorded with apertures of 4- and 5-μm diameter were found to agree well with Keller's theory as well as with the well-known Fraunhofer theory of diffraction. However, the diffraction patterns recorded with apertures of 1.3- and 2.5-μm diameter were found not to agree with predictions of Keller's theory; they also did not agree with predictions by the classical vector diffraction theory. In particular, the pattern formed by the 1.3-μm aperture con-

tained only a central bright spot that engulfed what was expected to be the first dark ring (the first minimum in the classical Airy-disk diffraction pattern), with none of the alternating bright and dark rings that one would ordinarily expect. The cause of this discrepancy is unknown, though it has been conjectured that the cause may be related to the thicknesses of the aperture foils.

This work was done by Yaujen Wang and Marija S. Scholl of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Experimental Investigation of Far-Field Diffraction by Normally Illuminated Circular Apertures of Wavelength Dimension,"* ***write in 33*** *on the TSP Request Card.* NPO-18430

Measurements of Turbulence in Boundary-Layer Flows

Fluctuations of velocities were analyzed with respect to various mathematical models of turbulence.

A report describes an experimental study of turbulence in two boundary-layer flows with adverse gradients of pressure. The flows were produced about a cylinder oriented with its axis along that of a low-speed wind tunnel of rectangular cross section.

The adverse gradient of pressure in each experiment was imposed on the downstream portion of the flow by use of flexible wind-tunnel walls that were made to diverge. In the first experiment, the adverse gradient of pressure was chosen to cause rapid growth of the boundary layer without separation; in the second experiment, the gradient was increased slightly to cause separation of the boundary layer. In both experiments, all three components of flow velocity were measured simultaneously as functions of time by a laser Doppler velocimeter, and skin friction was measured by an oil-flow interferometer.

The measured velocities were decomposed into mean and fluctuating parts, which were then used to compute Reynolds-average statistics (correlations among fluctuating components). These statistics included all 6 Reynolds-stress components (double products of the fluctuating velocity components) and all 10 triple-product correlations.

Analysis of the results revealed strong similarities between the two experimental flows and prior experimental free-shear-layer flows. Eddy viscosities, rates of dissipation of kinetic energy, and pressure-strain rates were computed from the experimental data. Quantities computed from the data were compared with corresponding quantities predicted by various mathematical models of turbulence.

This work was done by David M. Driver of **Ames Research Center**. *Further information may be found in AIAA paper 91-1787, "Reynolds Shear Stress Measurements in a Separated Boundary Layer Flow."*

Copies may be purchased [prepayment required] from AIAA Technical Information Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500. ARC-13156.

INDUSTRY LEADERS

Profiles of Pathsetting Companies In The Photonics Field

EASTMAN KODAK COMPANY
SOLID-STATE IMAGERS

For the past 17 years, Eastman Kodak Co., Rochester, NY, has been producing high-performance solid-state image sensors. Kodak's world-class facility houses research, design, fabrication, packaging, and testing of imagers and ASICs. Capabilities include production of area and linear sensors for a variety of commercial, medical, industrial, and aerospace applications.

The Kodak KAF-series full-frame sensors are available with resolution from .4 million to 6.3 million pixels. Output data rates of 20 MHz per channel allow much faster frame rates than typical imagers designed for slow-scan applications. Ultra-low dark current of <10 pA/cm^2 enables room temperature operation for most applications and moderate cooling for those involving extended exposures. Devices with true antiblooming are available for protection up to 1000x saturation for high-light or variable lighting conditions.

The Kodak KAI-series video rate interline devices feature a 2.1 million pixel HDTV sensor. Progressive-scan (noninterlaced) imagers with full resolution readout with every capture also are available featuring pixel counts as high as 1K x 1K. Support chips for analog and digital signal processing simplify system design.

The Kodak KLI-series includes a family of monochrome and tricolor linear solid-state image sensors for high-resolution, high-dynamic-range scanning applications. The color devices have only an 8-pixel interchannel spacing and one readout register per color, which eliminates odd/even pixel differences. These second-generation products have individual exposure control for each color and are capable of data rates up to 10 MHz per channel.

Evaluation boards are available for all imagers. These include clock drivers, timing circuits, DC bias voltages, and correlated double-sampled analog video output.

Contact: Helen Titus, Eastman Kodak Co., Rochester, NY 14650 Tel: 716-588-7612; Fax: 716-477-4947.

COHERENT INC.
LASER GROUP

Coherent Inc. was founded in 1966 to extend the limits of laser technology and build high-performance laser systems for customers in the scientific, medical, and industrial markets.

Today, Coherent is an international corporation with approximately 1500 employees and more than two dozen sales and service offices on six continents. The company consists of five distinct divisions: Components Group, Industrial Group, Lambda Physik, Laser Group, and Medical Group. Each division provides unique laser solutions to meet a diverse range of customer requirements.

Coherent's Laser Group (CLG) is a leading supplier of ion, dye, CO_2, ultrafast, and solid-state laser systems for scientific, OEM, and industrial laser users. CLG also serves as a central resource for many of the laser technologies developed and used in other divisions.

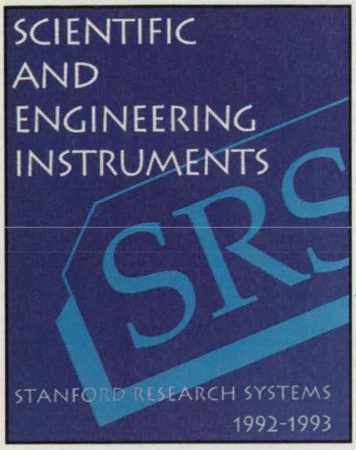
The Laser Group's business is structured to address the traditional scientific market and the growing original equipment manufacturer (OEM)/industrial market. CLG collaborates with many scientific and industrial equipment manufacturers to design its lasers.

Contact: Coherent Laser Group, 5100 Patrick Henry Drive, Mail Stop P45, Santa Clara, CA 95054. Tel: 1-800-527-3786; Fax: 1-800-326-1170.

STANFORD RESEARCH SYSTEMS INC.

PRECISION ELECTRONIC TEST INSTRUMENTS

Stanford Research Systems manufactures electronic products having exceptional performance, reliability, and value. A leading producer of small signal recovery instruments, SRS offers lock-in amplifiers, gated integrators/boxcar averagers, digital delay and pulse generators, photon counting instruments, optical choppers, fast current and voltage preamplifiers, and high-voltage power supplies.



The SRS product line recently has been expanded to include general-purpose test and measurement instruments such as synthesized function and arbitrary waveform generators, FFT spectrum and network analyzers, time interval and frequency counters, thermocouple monitors, LCR meters, frequency standards, and programmable filters.

SRS has combined innovative analog and digital circuitry to create the new DSP Lock-In Amplifiers—a classic example of the rejuvenation of a mature product through the use of digital signal processing technology. These unique DSP Lock-In Amplifiers are available only from SRS.

The company's signal recovery instruments are applicable to low-light-level detection for chemical and physical analysis, spectroscopy, LIDAR (time of flight), and high-precision timing and amplification. Test applications include precision frequency and time interval measurements; spectrum/network (audio, mechanical vibration, and acoustical) analysis; accurate resistance, capacitance, inductance, and temperature measurements; and signal/arbitrary waveform synthesis.

Contact: Daniel R. Melick, Stanford Research Systems, 1290 D Reamwood Ave., Sunnyvale, CA 94089. Tel: 408-744-9040; Fax: 408-744-9049.

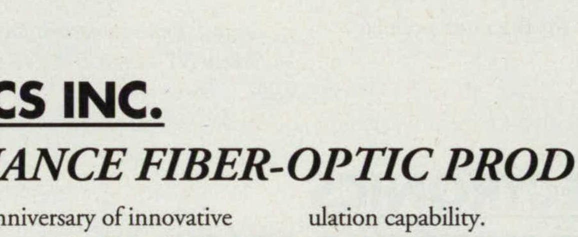
E-TEK DYNAMICS INC.

HIGH-PERFORMANCE FIBER-OPTIC PRODUCTS

E-TEK is celebrating its 10th anniversary of innovative design, development, and manufacturing of high-performance fiber-optic products. The company's expanding product family includes high-performance optical isolators, a complete line of couplers, electro-optic modulators, laser instruments, and fiber-optic learning kits.

Laser instruments include the Programmable Laser Diode Sources—the smallest, lightest, and most stable wavelength-tunable laser sources available. Applications include optical amplifier characterization, spectral filter testing, optical isolator characterization, and WDM fiber coupler testing.

E-TEK's customized wavelength narrow-linewidth laser sources provide the narrowest linewidth available and permit the user to specify the wavelength to 0.1 nm. The Multi-Channel Laser Diode Controller offers up to 16 plug-in modules, stabilized current/power and temperature control boards, and an electric mainframe with an RS-232 interface. It features user-configurable laser sources, ultra-stable optical power output, a double insulation package for thermal stabilization, and internal/external on/off modulation capability.



E-TEK has developed the industry's first highly-automated fiber coupler production workstation, which permits experimental fabrication of single mode and multimode fused biconical taper fiber couplers. Also available is the Laser Diode Test System, a remote-controlled test station suitable for multiple diode laser characterization, reliability and burn-in testing, and accelerated life testing.

E-TEK's passive components include a range of isolators, including bullet-size polarization-insensitive fiber isolators. The company also offers the first high coupling efficiency laser interfaced fiber interface, which provides nonisolator coupling directly from the laser to the fiber tip, and the Miniature Optical Freespace Isolator, which features an epoxy-free, metal-bonded package with laser-weldable housing.

Contact: Ming Shih, Director of Commercial Products, E-Tek Dynamics, Inc., P.O. Box 611120, San Jose, CA 95161-1120. Tel: 408-432-6300; Fax: 408-432-8550.

BURLEIGH INSTRUMENTS INC.

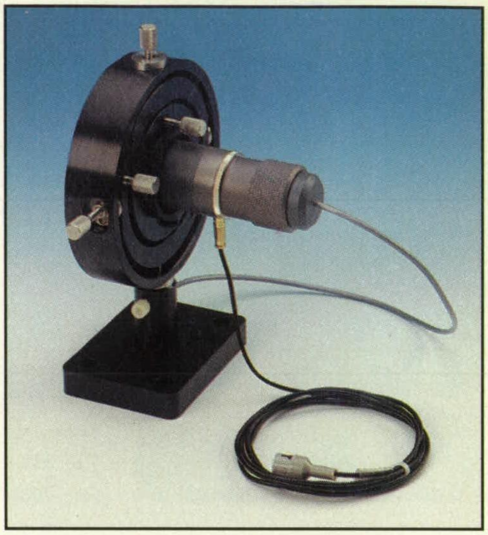
ULTRA-PRECISE LASER CHARACTERIZATION

For more than two decades, Burleigh Instruments has pioneered the design and manufacture of high-precision spectral analysis and wavelength measurement instrumentation for CW and pulsed lasers. As a leader in Fabry-Perot and Michelson-based interferometric technology, Burleigh products for laser diagnostics provide the highest-level of performance even for the most demanding applications.

The new Burleigh SA^PLUS is the highest Finesse confocal Fabry-Perot interferometer available. With Finesse greater than 250, the SA^PLUS provides the highest quality spectral measurements of CW lasers for linewidth, mode structure, and frequency shift. With a choice of free spectral range of 2 GHz and 8 GHz, the resolution of the measurements are better than 8 MHz and 32 MHz respectively.

The SA^PLUS also is the most versatile and affordable optical spectrum analyzer available. Easily interchangeable mirror sets allow operation anywhere between 250 and 5000 nm. As research moves to different wavelengths, even into the ultraviolet or infrared portions of the spectrum, the SA^PLUS can handle spectral analysis requirements with a simple change of mirrors. Interchangeable mirror sets for the most popular wavelengths are available from stock.

The SA^PLUS is extremely easy to use even when changing wavelength ranges. Mirrors can be changed and the interferometer aligned in a just a few minutes. Improved control electronics and a new high-speed detector assembly, with sensitivity to 10 nanowatts, allow for spectral analysis of even low-power laser signals.



Contact: Brian Samoriski, Burleigh Instruments Inc., Burleigh Park, Fishers, NY 14453. Tel: 716-924-9355; Fax: 716-924-9072.

EG&G OPTOELECTRONICS

PHOTONIC PRODUCTS FOR UV TO IR

Based in Sunnyvale, California, the EG&G Optoelectronics Group consists of six autonomous divisions including Canada Ltd., Electro-Optics, Heimann Optoelectronics, Judson, Reticon, and Vactec. The group provides a full line of standard and custom photonic products for use in the ultraviolet, visible, and far infrared spectrum. The parent, EG&G Inc., headquartered in Wellesley, Massachusetts, is a diversified Fortune 200 company with over 30,000 employees. Its activities encompass more than 150 business units engaged in state-of-the-art technology and manufacturing, as well as operational and scientific management services.

The Optoelectronics Group was formed in 1992 to coordinate the marketing strategies and sharing of technology between its six divisions, each with years of experience in combining light and electronics for defense, aerospace, communications, medical equipment, scientific instrumentation, automotive, consumer, and industrial applications.

Contact: John P. Skurla, Director of Marketing, EG&G Optoelectronics, 345 Potrero Avenue, Sunnyvale, CA 94086-4197. Tel: 408-245-2060; Fax: 408-720-0794.

Product offerings include emitters, laser diodes, UV-VIS photodiodes and receivers, flashlamps, arc lamps, PID lamps, machine vision strobes, TV camera tubes, pyroelectric and thermopile IR sensors, laser diode arrays, amorphous silicon large area detectors, IR detectors and coolers, CCD image sensors and camera systems, photocells, phototransistors, retro and interrupter optical switches, and analog optoisolators.

In addition to its standard products, EG&G offers custom engineering services ranging from product definition and prototype design to full-scale production, including contract design and manufacturing of electro-optic subassemblies and systems.

MELLES GRIOT INC.

OPTICS, COMPONENT LASERS, AND INSTRUMENTATION

For the last 24 years, Melles Griot has provided optics, component lasers, and optical instrumentation for industrial, scientific, medical, and commercial applications. The company has manufacturing operations in the US, Europe, and Asia, as well as direct stocking and distribution subsidiaries in 12 countries.

In the US, Melles Griot's Catalog Division in Irvine, California stocks 150,000 components to support 8000 separate items in its Optics Guide 5. Most of these are available for next-day delivery. The Laser Division in Carlsbad, California is the world's largest supplier of helium-neon (HeNe) lasers, and Boulder, Colorado's Electro-Optics Division manufactures diode laser assemblies as well as diode-laser drivers and instrumentation. The Optics Division in Rochester, New York supplies flat-field scan lenses and multi-element optical assemblies to the graphics arts industry. Around the world, Melles Griot manufactures optical and mechanical assemblies in Japan, classical optics in Taiwan and Germany, infrared and synchrotron optics in France, and high-power optics in the Isle of Mann. Melles Griot Photon Control in England manufactures automated fiber-optic positioning and alignment equipment (see photo) as well as optical tables and opto-mechanical hardware.

Contact: Melody Honadel, Melles Griot, 1770 Kettering St., Irvine, CA 92714. Tel: 1-800-835-2626 or 714-261-5600; Fax: 714-261-7589.

Melles Griot recently has expanded into the field of optical instrumentation, and offers a complete line of products designed for beam diagnosis. These include broad-band power meters that measure power from micro-watts to 30 watts, easy-to-use optical spectrum analyzers that cover the full visible range with a single set of mirrors, and stand-alone and card-based beam scan systems. A new device, the WaveAlyzer, is the first moderately-priced instrument for directly measuring coma and spherical aberrations in a propagating beam.

PHOTOMETRICS LTD.

HIGH-PERFORMANCE COOLED CCD CAMERAS

Incorporated in 1979, Photometrics is a leading manufacturer of high-performance cooled CCD camera and detector systems in fields as diverse as life sciences, high-energy physics research, astronomy, spectroscopy, x-ray imaging, semiconductor analysis, and motion picture special effects.

Photometrics offers a complete range of high-performance camera systems designed to provide low-noise, high-resolution image capture. These products are completely different from conventional video cameras and other scanning imagers. Photometrics' cooled imaging systems take full advantage of the performance qualities inherent in scientific-grade CCD imagers, delivering unmatched response linearity, quantum efficiency, and signal-to-noise ratios. These cameras offer high dynamic range (12- to 16-bits of intensity data per pixel) using two-dimensional CCD sensors with resolutions from 384 x 576 to 3072 x 2048 pixels, and employ sophisticated digital controllers and signal processing electronics to ensure the most accurate image possible.

Contact: Photometrics Ltd., 3440 East Britannia Drive, Tucson, AZ 85706. Tel: 602-889-9933; Fax: 602-573-1944.

Photometrics' standard camera line includes the series 200 slow-scan cooled CCD camera, the STAR 1 low-cost cooled CCD imaging system, the SDS®9000 16-bit cooled CCD detector for spectroscopy, and the new PXL high-speed, modular camera system. Photometrics' Advanced Technologies Group develops custom imaging systems for such diverse requirements as very high frame rates, large CCD arrays and mosaics, and fiber-optically coupled CCDs.

SPECTRA-PHYSICS LASERS

MANUFACTURER OF LASER SYSTEMS

Spectra-Physics Lasers provides high-performance laser systems to scientific and commercial customers. The company is organized into core business units, targeting key market segments. Each business unit maintains its own R&D, manufacturing, and support functions. Although autonomous, these individual units are based at the same location and work closely together at a variety of levels to enhance both customer focus and product flexibility.

The OEM Business Unit focuses on commercial applications requiring ion- or diode-pumped solid-state lasers.

Quanta-Ray provides high-energy pulsed Nd:YAG lasers and tunable solid-state devices, including Optical Parametric Oscillators (OPOs).

Ultrafast Laser Systems manufactures ultrafast solid-state, CW tunable, and high-power ion lasers for research and industrial applications.

The Components and Accessories Group combines optical design, fabrication, and coating technology with state-of-the-art machine tool capabilities to provide low-cost optical subsystems to OEM customers.

Contact: Mark Enright, Spectra-Physics Lasers, 1330 Terra Bella Avenue, Mountain View, CA 94043. Tel: 415-966-5516; Fax: 415-961-7101.

NESLAB INSTRUMENTS INC.

RECIRCULATING CHILLERS FOR LASER COOLING

For the past 30 years, NESLAB Instruments has designed and manufactured recirculating chillers for cooling lasers, optics, photonics, and imaging equipment. These closed-loop chillers improve equipment performance by replacing unclean or unpredictable tap and building water. Unlike tap water, the coolant circulated with a chiller is clean and free of minerals, organic matter, rust, or pollutants.

The chiller's innovative hinged-hood design allows easy access to internal components, including the reservoir fill cover. Industrial grade pumps provide flows of up to 60 psi. The chillers feature oversized, hermetically-sealed refrigeration compressors for steady cooling and trouble-free, 24-hour-a-day operation. They also provide heat load removal up to 75 kilowatts spanning temperature ranges from 5 to 35 °C.

Compact and portable, the NESLAB chillers feature LED temperature displays, with several operating status gauges on the front panel for convenient system monitoring. Built-in controllers allow the user to set the temperature of the circulating fluid. A choice of three controllers allows selection of either basic control functions or additional monitoring and safety interlock functions.

The HX series of recirculating chillers utilizes an HCFC refrigerant, which is universally accepted as an environmentally friendly alternative to the more damaging CFC refrigerants many manufacturers use. NESLAB also offers a wide range of customizing options for these chillers including deionization packages, extended temperature ranges, safety interlocks, stainless steel or plastic components, and UL approval. NESLAB recirculating chillers are available for OEM arrangements.

Contact: Deborah Luddington, NESLAB Instruments Inc., P.O. Box 1178, Portsmouth, NH 03801. Tel: 603-436-9444; Fax: 603-436-8411.

ROFIN-SINAR INC.

LASERS FOR INDUSTRIAL PROCESSES

Rofin-Sinar, a Siemens AG company, is a leading manufacturer of industrial lasers that include CO_2 and Nd:YAG, as well as related beam delivery systems such as fiber optics. With facilities in the US, Europe, and Japan, and installations that exceed 3200, Rofin-Sinar is pioneering advanced technologies and expanding the use of laser processing technology.

Rofin-Sinar lasers are used for cutting, welding, microwelding, drilling, heat treating, cladding, marking, and reflow soldering in diverse industries that include aerospace, automotive, job shops, metal fabrication, electronics, and medical components. The scope of products includes CO_2 lasers from 80 W to 15 kW; pulsed Nd:YAG lasers from 150 W to 1 kW; continuous wave Nd:YAG lasers from 20 W to 2 kW; laser marking systems from 20 to 150 W; and complete fiber-optic systems for laser beam delivery.

Contact: Richard Walker, Vice President, Rofin-Sinar Inc., 45701 Mast Street, Plymouth, MI 48170. Tel: 313-455-5400; Fax: 313-455-2741.

At its Plymouth, Michigan facility, Rofin-Sinar has assembled the largest range of laser technology in the US dedicated to application research. The application research center houses CO_2 and Nd:YAG lasers and marking systems. Support equipment includes five-axis positioning, robotic beam delivery manipulation, fiber optics, a metallurgical laboratory, and personnel whose expertise encompasses weld joint design, metallurgical analysis, optics/fiber optics, and workholding design.

Rofin-Sinar's investment into research and development has led to the introduction of the RS 15000 RF 15 kW CO_2 laser capable of high-integrity welds at greater depths and faster speeds, and a 2 kW continuous wave Nd:YAG laser system. In 1994 the company will introduce a compact multi-kilowatt diffusion-cooled CO2 laser that eliminates the need for complex gas circulation systems, is simple to operate, and requires minimal maintenance.

PARKER HANNIFIN CORPORATION DAEDAL DIVISION

OPTO-MECHANICAL POSITIONERS

Daedal Opto-Mechanical positioning components and optical accessories are used widely in plants and laboratories for laser setups and test stands that require stable component mounting and exact positioning. Products include optical mounts, mirrors, platforms, stands, and a variety of other optical bench hardware. Daedal also offers the industry's largest selection of miniature and standard ball slides, cross roller slides, single- and multi-axis linear position stages, digital micrometer stages, rotary tables, and drive mechanisms.

The Opto-Mechanical products are available directly from the company's 116-page catalog. Virtually every standard catalog product offered is in stock for next day shipment.

In addition to standard catalog products, Daedal offers extensive design services and a comprehensive line of positioning technologies. Application-specific positioning products include bridge and gantry systems, large-diameter/high-payload rotary tables, and high-performance motorized positioning systems. Daedal has built positioning systems with speed requirements from 1 mm/hour to over 120 in./sec., an X-Y system that accurately positions 1 ton, and a table with a measured resolution of 2.5 millionths and less than 2.5 millionths backlash.

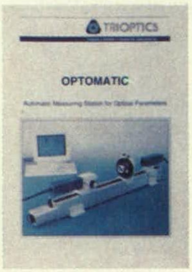
Contact: Parker Hannifin Corp., Daedal Division, Sandy Hill Road, P.O. Box 500, Harrison City, PA 15636. Tel: 1-800-822-7001; Fax: 412-744-7626.

Daedal utilizes a diverse range of bearing and drive components, including belt drives, ball bearings, precision ground and rolled thread ball screws, cross roller bearings, linear motion guides and bushings, rotary bearings, manual and digital micrometers, and precision ground and lapped worm gears. The company also manufactures precision leadscrews in a variety of leads, accuracy classes, and nut types made from high carbon steel and hardened to Rc 58-60. Daedal certifies the lead accuracy with a laser interferometer.

LASER TECH BRIEFS

LITERATURE SPOTLIGHT

Free catalogs and literature for Laser Tech Briefs' readers. To order, circle the corresponding number on the Readers Information Request Form (page 33).



AUTOMATIC OPTICAL TESTING

OPTOMATIC is the first fully-automated test instrument featuring fast, ultra-accurate, objective performance characterization of optical components and lens systems. Focal length, flange focal length, radius of curvature, angles and power of wedges and prisms, MTF and centering errors can be precisely measured. Typical accuracy is 0.05% for focal length, 0.002 diopter for power of prisms and less than 1 arc sec. for angles.

Mildex Inc.

For More Information Write In No. 300

WORLD'S BEST SPHEROMETERS

Super-Spherotronic features NBS traceable, calibration level accuracy combined with automated operation and the ease of use needed for production and QC. The Ultra-Precise probe is accurate to ±0.2 μm, radius of curvature is accurate to 0.01%. Spherocompact is a digital, hand-held unit featuring a Micron resolution, linear encoder. It measures in mm or inches. RS-232 interface is standard.

Mildex Inc.

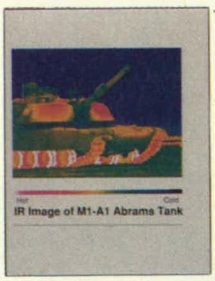
For More Information Write In No. 301

OPTO-MECHANICAL PRODUCT GUIDE

Daedal's new Opto-Mechanical catalog contains hundreds of laboratory bench optical mounts, positioning devices and optical hardware. Complete specifications, dimensions and pricing are included. All products listed can be ordered by phone or fax, can be charged to Visa or Mastercard, and are shipped free to anywhere in the continental US. Tel: 800-245-6903; Fax: 412-744-7626.

Daedal Division
Parker Hannifin Corporation

For More Information Write In No. 302



SEE THE HOT SPOTS?

An M1-A1 tank may not be attacking you now, but a hot spot probably is. Industrial and research infrared cameras are available to get or keep you out of the hot seat. For more information, call 513-573-6275, or fax 513-573-6290. Address: 7500 Innovation Way, Mason, OH 45040.

Cincinnati Electronics, Detector Labs

For More Information Write In No. 303

CCTV CAMERAS & SYSTEMS

A New Short Form Catalog features color and monochrome CCD cameras, including high performance, low light level and digital output models. Cohu cameras are designed and manufactured in the USA for security/surveillance and electronic imaging applications.

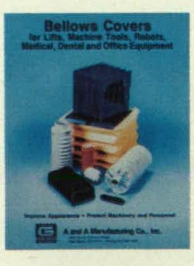
Cohu, Inc., Electronics Division

Security/surveillance applications: Circle No. 304
Electronic Imaging applications: Circle No. 322

SPECIALTY GAS AND EQUIPMENT CATALOG

Free! The 1993 rare and specialty gas and equipment catalog from Spectra Gases of Irvington, NJ, contains specifications on rare gases, excimer laser gas mixtures, halogen gas premixtures, helium-3 and isotopic gases, research gases and mixtures, gas safety cabinets, automatic and manual gas-handling systems, and related equipment. Krypton and argon ion-laser tube remanufacturing, halogen scrubbers, and "oil free" vacuum pumps are among the products and services highlighted.

For More Information Write In No. 305

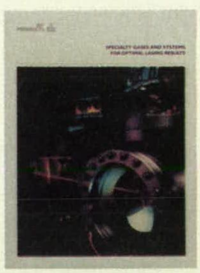


CAMERA BELLOWS

Gortite custom-engineered bellows-type covers are available for cameras, enlargers, medical and dental machinery, machine tools, robots, precision slides, automated handling equipment, and other moving machinery. The covers protect machinery from oil, dirt, chips, and other contaminants. Made of durable elastomer-coated fabrics, Gortite bellows include linear bearing way covers, ball screw and rod covers, and die set shields. Write for Bulletin PR-100. Tel: 414-786-1500.

A and A Manufacturing Company

For More Information Write In No. 306



TOTAL GAS MANAGEMENT

An integrated package of products and services designed to produce optimal lasing results for you. Ultraray® gases for excimer, CO_2, and chemical lasers, local stocking, gas handling and purification equipment, gas cabinets, laser applications lab, emergency response teams, and 800 line for technical support.

Air Products and Chemicals, Inc.

For More Information Write In No. 307

QUARTZ & SILICE

produces laser crystals: Nd:YAG, Nd:YLF; crystals for non-linear optics: KDP, POM, LNO, LTO; single crystal wafers of InP; garnet crystals and epitaxial films: GGG, SGGG, YIG, Ce:YAG; and, crystals for x-ray spectrometry: LiF, Beryl, T1AP and PET. Tel: 216-248-7400 or toll-free 1-800-472-5656; Fax: 216-349-6979.

BICRON

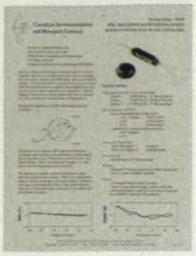
For More Information Write In No. 308

LASER CHARACTERIZATION BROCHURE

The Burleigh Instruments Laser Diagnostic Systems brochure features the company's complete line of Fabry Perot Interferometers and Wavemeters for ultra precise wavelength measurement, and spectral analysis for both CW and Pulsed lasers. Included in this comprehensive brochure are Fabry Perot Etalons, control electronics, detectors, and optical coupling accessories. Call 716-924-9355.

Burleigh Instruments Inc.

For More Information Write In No. 310



POLARIZATION MAINTAINING FIBER OPTICS

Extended temperature range polarization maintaining couplers for -55 to +125 °C operation, variable ratio couplers, fiber polarization splitters, 3 dB TM mode polarizing couplers and WDM pump couplers are described. Components are available in cascaded splice-free assemblies. Tel: 416-332-1353; Fax: 416-332-1808.

Canadian Instrumentation & Research Ltd.

For More Information Write In No. 311

LASER TECHNOLOGY AND APPLICATIONS

An 18-page brochure available from Rofin Sinar, Inc. provides a concise examination of laser technology and its expanding applications in the manufacturing environment. Detailed are the elements and concepts of lasers critical to modern industry: versatility and flexibility; precision, control, and speed; and the laser's present and potential applications in welding, cutting, drilling, surface treatment, and product identification. Individual sections discuss CO_2 and Ng:YAG lasers, laser marking systems, and Rofin Sinar's capabilities and resources.

Rofin Sinar, Inc.

For More Information Write In No. 312

NEW COUNTDOWN FOR LASER PULSE SELECTION

The Model 305 presettable countdown electronics is a high speed synchronous divider that generates an electronic trigger pulse, locked in time with the input stimulus. The output trigger rate is integer-related to the input clock rate by a six-decade thumbwheel switch on the front panel. The instrument's primary application is to provide all timing, delay adjustments, and output signals required to drive a variety of laser pulse selection modulation systems. The countdown will operate to C/2L rates of 140 Mhz, has a built-in 16 nsec delay and provides a high speed TTL and analog timing pulse out.

Conoptics, Inc.

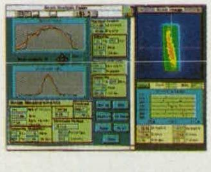
For More Information Write In No. 313

HIGH-RESOLUTION FRAME GRABBER

SILICON VIDEO MUX is a single-board frame grabber that provides the PC/AT with an interface to high-bandwidth, high-resolution video sources. Up to 8000 pixels per line and 1024 lines per field are supported. An adaptable timing generator allows digitization from area-scan devices as well as from medical equipment and videotape players. Tel: 708-498-4002; Fax: 708-498-4321.

EPIX, Inc.

For More Information Write In No. 314



BEAM ANALYSIS & DIAGNOSTICS

A new 12-page catalog describes in detail the Beam Analysis VI application and its optional programming tools. Beam Analysis VI is a video-based system for real-time beam diagnostics, characterization and laser tuning.

GTFS Inc.

For More Information Write In No. 315

NEW INFRARED OPTICS CATALOG FOR RESEARCHERS, MANUFACTURERS, AND OPTICAL ENGINEERS

II-VI Incorporated, Saxonburg, PA, a worldwide leader in IR laser optics, is now offering a 48 page, full color optics catalog. This catalog is designed to assist researchers, manufacturers and users with the proper selection and specification of optics. It features detailed information on all significant aspects of infrared optics, including IR Materials.

II-VI Incorporated

For More Information Write In No. 316

HIGH GAIN DETECTOR FOR LIGHT MEASUREMENT

A new SHD-1 data sheet describing the SHD033 High Gain Silicon Detector for low level light measurement in any optical unit is available from IL. The device provides the gain of a photomultiplier with the stability of a silicon photodiode. The SHD033 is used with the IL1700 Research Radiometer/Photometer.

International Light, Inc.

For More Information Write In No. 317

RAMAN SPECTROSCOPY PRODUCTS

Holographics Imaging Spectrographs for Raman and laser-induced fluorescence spectroscopy, Holographic Notch and Super-Notch™ filters for laser line rejection and holographic laser bandpass filters for Raman and fluorescence spectroscopy, holographic diffusers and protection screens, holographic transmission gratings in 350 nm and 1064 nm range for pulse compression and pulse shaping applications. Tel: 313-665-8083; Fax: 313-665-8199.

Kaiser Optical Systems, Inc.

For More Information Write In No. 318

LASER DETECTORS AND INSTRUMENTATION

This catalog features information on the entire product line. The reader will find specific technical information on Molectron's popular joulemeter probes and instruments; Power-Max™ laser power meters, broadband radiometers and detector amplifiers; pyroelectric hybrid detectors; and thin-film IR polarizers and free-standing, wire-grid polarizers. Contact Burt Mooney. Tel: 800-366-4340; Fax: 503-620-8964.

Molectron Detector, Inc.

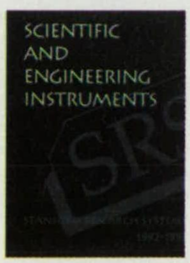
For More Information Write In No. 319

LASER DIODE OPTICS

A full line of precision optics offered by Optima Precision, Inc., West Linn, Oregon, is for use with laser diode systems including glass & plastic objective and collimating lenses, collimated diode lasers, spherical & cylindrical lenses, beamsplitters, dielectric mirrors, windows, filters, anamorphic, and cube prisms. Applications include alignment, measurement, inspection systems, particle sensors, and bar code readers. Contact Dick Schmitz. Tel: 503-638-2525; Fax: 503-638-4545.

Optima Precision Inc.

For More Information Write In No. 320

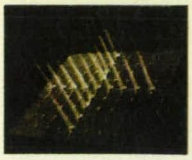


PRECISION TEST AND MEASUREMENT EQUIPMENT

Stanford Research Systems' 1992-93 Catalog contains complete specifications, technical discussions and application notes on their line of scientific and engineering instruments. This 160 page catalog includes the latest function generators, spectrum analyzers, lock-in amplifiers and delay generators, and is a useful reference for a wide range of test and measurement applications. Tel: 408-744-9040.

Stanford Research Systems

For More Information Write In No. 321



DIFFRACTIVE OPTICS

Teledyne Brown Engineering builds custom diffractive optics to meet customers' specifications. State-of-the-art proprietary software enhances design and analysis capabilities and is backed by on-sight fabrication and test facilities to provide a cost-effective process. These diffractive optics advance OEM system applications, as well as research projects.

Teledyne Brown Engineering

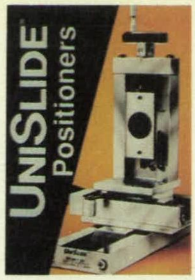
For More Information Write In No. 369

TELEDYNE GURLEY OPTOGRAPHICS

Brochure describes our optographic capabilities, including, preparation of precision patterns, duplication of patterns on high resolution plate, or with vacuum deposited chrome or other metals on glass and other substrates. We also provide precision resolution targets, reticles, and discs.

Teledyne Gurley Optographics

For More Information Write In No. 323

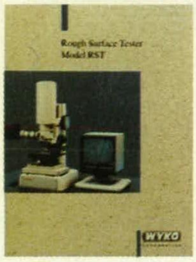


POSITIONING SLIDES AND BEARINGS

Catalog G features over 950 versatile UniSlide Assemblies. They are manually driven linear bearings, screw driven slides and rotary tables. Cost efficient. Ideal for positioning, feeding, gauging and fixturing. Come in five widths from 1.5" to 9"; travels from 0.5" to 90". Non-magnetic, reliable XYZ. Catalog includes prices and engineering information. Tel: 1-800-642-6446 or 716-657-6151; Fax: 716-657-6153.

Velmex, Inc.

For More Information Write In No. 324

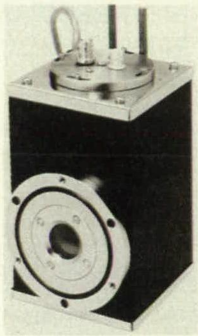


ROUGH SURFACE PROFILER

The WYKO RST rapidly measures roughness and step heights to 100 µm with vertical resolution better than 0.3 nm (0.012 µin.) on surfaces such as textured aluminum and steel, etched silicon, plastics, magnetic tape and diskettes, ceramics, and even paper. Tel: 1-800-FON-WYKO.

WYKO Corporation

For More Information Write In No. 325



COOLED PMT HOUSING

The AMHERST Model 4100 shown here incorporates all of the 'options' offered by the competition in the best housing available for IR and Fluorescence applications. Call for details on our cooled and ambient housings for all PMT's. Tel: 1-800-344-0075.

Amherst Scientific Corp.

For More Information Write In No. 326

P360F POWER GRABBER

The P360F Power Grabber from DIPIX combines flexible frame grabbing, a TMS320C30 DSP and up to 80 MBytes image memory in a single PC slot. A piggy-back display card with resolution of 1280 x 1024 is also available.

Dipix Technologies Inc.

For More Information Write In No. 327

FOLK-1000

E-TEK's Fiber Optic Learning Kit (FOLK-1000) is the ideal tool for learning the basics of fiberoptics technology. The kit includes a control unit, experiment accessories, a lab manual, and a textbook. This kit is ideal for students, engineers and researchers. Contact John Baker. Tel: 408-432-6300; Fax: 408-432-8550.

E-TEK Dynamics, Inc.

For More Information Write In No. 328

PHOTODIODE DATA BOOK FOR DESIGNERS AND ENGINEERS

EG&G Vactec has published a 128-page photonics databook. This designer's reference manual is a comprehensive guide to understanding, selecting, and configuring a myriad of conventional photodetector circuits utilizing over 100 standard type silicon photodiode products including detector arrays.

EG&G Vactec

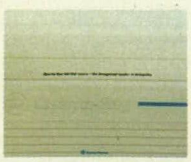
For More Information Write In No. 329

OPTICS FOR METROLOGY

This 106-page catalog gives information, including prices, on X-Y tables, microfinishing equipment, toolmakers' microscopes, alignment and monocular zoom microscopes, borescopes and miniborescopes, and fiber optic and miniature illumination systems. Also described are centering microscopes, optical cutting tool geometry analyzers, and more.

Titan Tool

For More Information Write In No. 330



The latest brochure from the Quanta-Ray business unit of Spectra-Physics lasers describes their line of high energy pulsed Nd:YAG solid state laser products. Twenty-five models offering 1064 nm output energies from 200 mJ to 2 J, standard repetition frequencies of 10, 30, 50, and 100 Hz, integral harmonic generation and separation, injection seeding, and full computer control capability are described. Spectra-Physics Lasers, Tel: 800-456-2552 Option 5; Fax: 415-964-3584.

Spectra-Physics Lasers

For More Information Write In No. 331

HIGH PERFORMANCE CCD TECHNOLOGY EXPLAINED

Photometrics has produced a 40-page technical booklet describing CCD technology for quantitative electronic imaging applications. This booklet explains the theory of CCD imaging sensors, readout modes, performance characteristics and trends in solid-state imaging.

Photometrics, Ltd.

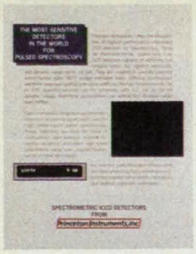
For More Information Write In No. 332

GENTEX OPTICS BROCHURE HIGHLIGHTS FILTRON®

Gentex Optics now offers a brochure for designing your next custom filter, with Filtron. This lightweight polymeric substrate provides a cost-effective alternative to color filter glass in a wide range of applications. It is compatible with most polymers to provide maximum configuration flexibility. Filtron absorbers are available in dye, resin, and finished formats. For further information, contact Gentex Optics, Inc., P.O. Box 336, Carbondale, PA 18407. Tel: 717-282-8600; Fax: 717-282-8555.

Gentex Optics, Inc.

For More Information Write In No. 333



A full-color informative brochure from Princeton Instruments, Inc., Trenton, NJ, describes the most sensitive intensified spectrometric CCD detector lines offered. These slow-scan cooled detectors are gatable down to 5 ns with a maximum sensitivity of 80 cts/pe. Three model lines are available: integrated ICCD, fiber-coupled modular ICCD (both are exclusive to Princeton Instruments), and the lens-coupled modular ICCD.

Princeton Instruments, Inc.

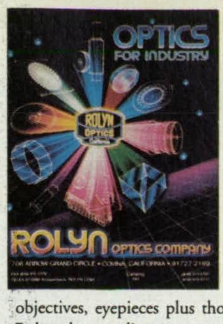
For More Information Write In No. 334

LASER WAVEFRONT ANALYZER

The model 13 WAS 001 WaveAlyzer measures both the phase and amplitude of a laser beam. It displays the wavefront profile and provides quantitative values for coma, astigmatism, spherical aberration and defocus. The WaveAlyzer provides 2-D and 3-D color contour maps of beam intensity distribution, phase profile and far field irradiance.

Melles Griot, Inc.

For More Information Write In No. 335



FREE CATALOG: OFF-THE-SHELF OPTICS

Free 130-page product catalog from Rolyn, the world's largest supplier of "off-the-shelf" optics. 24-hour delivery of simple or compound lenses, filters, prisms, mirrors, beamsplitters, reticles, objectives, eyepieces plus thousands of other stock items. Rolyn also supplies custom products and coatings in prototype or production quantities.

Rolyn Optics Co.

For More Information Write In No. 336

ELECTRONIC FILM IMAGING

Literature is now available detailing Mekel Engineering's line of custom film/paper transport systems...pin-registered or continuous movement including electro-mechanical design and hardware for: laser scanning, image digitizing, x-ray scanning, microdensitometer recording, phototypesetting, high-speed microfilm retrieval, medical imaging or any form of electronic imaging for analysis, storage and retrieval.

Mekel Eng.

For More Information Write In No. 337

Alpha Omega Instruments offers high precision, low noise thermoelectric cooler controllers for laser diodes and infrared detectors. All controllers feature P&I control with bipolar constant current to the TEC. Output capacities range from 0-5 to 0-600 watts. Prices start at $595.00. Alpha Omega Instruments Corp., P.O. Box 19230, Johnston, RI 02919. Tel: 401-934-9880.

Alpha Omega Instruments Corp.

For More Information Write In No. 338

HIGH VOLTAGE POWER SUPPLIES

This catalog from Bertran contains 100 pages of information on solutions to high voltage power supply requirements. Detailed product information on instruments, modules, and NIM power supplies is provided. Standard and custom designs are available for OEM or laboratory applications.

Bertran High Voltage

For More Information Write In No. 339

µLENS CYLINDRICAL MICROLENSES FOR LASERS DIODES

µLENS optics are a new class of miniature lenses, very fast, highly corrected, coated and uncoated, with diffraction-limited performance over numerical aperatures to 0.7. The Virtual Point Source (VPS700) or SAC Series µLENSes permit focusing or collimating laser diodes. Blue Sky Reaseach: 408-982-0471.

Blue Sky Research

For More Information Write In No. 340

E-O Technology

UTOS designs and manufactures lasers, precision optical components, and adaptive optical components/systems for aerospace/defense, scientific and industrial markets. This colorful brochure describes our range of products which includes ultra-compact, durable CO_2 lasers; transmissive and reflective optical systems; lightweight, stiff, thermally stable silicon carbide components; deformable and fast steering mirrors; wavefront control and compensated imaging systems; and a full line of custom coating services.

United Technologies Optical Systems, Inc.

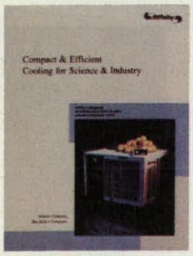
For More Information Write In No. 341

UV WAVEGUIDE LASERS

Potomac's compact RF discharge excimer lasers offer unique characteristics including 2000 Hz maximum pulse repetition rate, simplified operation and 110-volt, air-cooled operation. Applications include micromachining of diamond, glass, ceramics, polymers and thin metal films, surface analysis, injection locking, and dye laser pumping. Potomac also offers contract services. Potomac Photonics, Inc. 4445 Nicole Drive, Lanham, MD 20706. Tel: 301-459-3031. Fax: 301-459-3034.

Potomac Photonics, Inc.

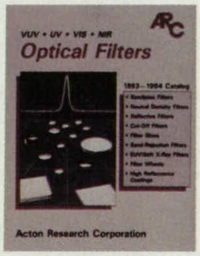
For More Information Write In No. 342



Affinity's F-Series chillers provide low-cost, efficient cooling from 1 kW to 50 kW. The modular design is available rackmountable, stand-alone, or configured to an OEM's cabinet. Features: digital microprocessor, unrestricted component access, and level, flow, and temperature alarms, with RS232 and interlock capabilities. Affinity also manufactures the compact R-Series chillers with capacities from 1 kW to 4 kW, and heat exchangers up to 100 kW. Contact Bob Copplestone, Affinity, Inc.. Tel: 603-473-8581.

Affinity, Inc.

For More Information Write In No. 343



OPTICAL FILTERS CATALOG

ARC's VUV-UV-VIS-NIR Optical Filters catalog features filters for the wavelength region extending from the Near-IR (1064 nm) to soft x-rays. Included are narrow and broadband UV filters, neutral density filters, reflective filters, bandpass filters, cut-off filters and UV filter glass.

Acton Research Corporation

For More Information Write In No. 344

LASER DIODE OEM SYSTEMS

Power Technology's new catalog features their complete line of high-quality diode laser systems and components. All systems are fully integrated to include optics and diode-driving electronics. The full product line includes wavelengths from 635 nm to 1550 nm, anamorphic and astigmatic correcting optics, precise beam pointing, thermoelectric control, a CDRH certified model, and many mechanical and electrical accessories. Tel: 501-568-1995; Fax: 501-568-1994.

Power Technology, Inc.

For More Information Write In No. 345

LASER TECHNOLOGY AND APPLICATIONS

An 18-page brochure available from Rofin Sinar, Inc. provides a concise examination of laser technology and its expanding applications in the manufacturing environment. Detailed are the elements and concepts of lasers critical to modern industry: versatility and flexibility; precision, control, and speed; and the laser's present and potential applications in welding, cutting, drilling, surface treatment, and product identification. Individual sections discuss CO_2 and Ng:YAG lasers, laser marking systems, and Rofin Sinar's capabilities and resources.

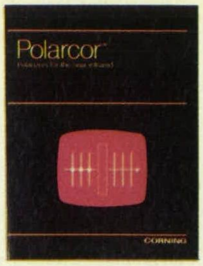
Rofin Sinar, Inc.

For More Information Write In No. 346

Thorlabs, Inc.'s latest catalog features 350 products organized in 5 sections as follows: mounting components featuring bases, posts, post holders, mirror mounts, lens holders, and clamps; opto-electronics featuring our line of detectors; laser diodes featuring a full line of visible laser diodes in the 670-690 nm range; fiber optics featuring 3M fiber, fiber launch systems, flexure stages, and ball lenses; fasteners and accessories. The 42 page catalog is a comprehensive product listing which pricing, descriptions and specifications.

Thorlabs, Inc.

For More Information Write In No. 347

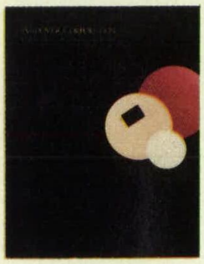


POLARCOR NEAR-IR GLASS POLARIZERS

Polarcor dichroic near-IR glass polarizers offer high contrast (to 10,000:1) and high transmittance (>90%). Features include 400 °C use temperature and large acceptance angles. Wavelengths from 632 to 2100 nm. In stock polarizer diameters of 6-25 mm, custom shapes with 2-30 mm diagonals possible. Contact Corning, Inc., Polarcor Sales, MP-21-4, Corning, NY. Tel: 607-974-7966.

Polarcor

For More Information Write In No. 348



Andover introduces its new 1993 OPTICAL FILTER GUIDE. This extensive 56 page guide features a general and technical section which contains a large amount of information regarding the usage and performance of interference filters and optical coatings. The products section lists Andover's complete line of standard and custom interference filters and optical coatings. Send for your free copy.

Andover Corporation

For More Information Write In No. 349

Lightning Optical's 32-page catalog outlines line of coated optics, laser cavities and fluoride laser crystals. The company specializes in Nd:YLF and Cr:LiSAF growth, fabrication and coating for diode and flashlamp pumping as well as manufacturing coated optics from 250-3000 nm. Tel: 813-938-0092.

Lightning Optical Corporation

For More Information Write In No. 350

MICROIMAGER DIGITAL CAMERA

A precision instrument meeting the highest performance standards, the MicroImager has been optimized for digital quantitative image acquisition. The MicroImager provides 1320 x 1035 pixels, and is operated in accumulation mode to suppress dark current and permit 12 bit digitization without cooling.

Xillix

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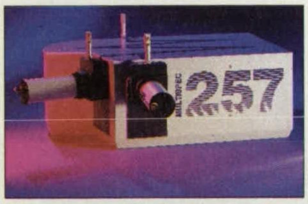
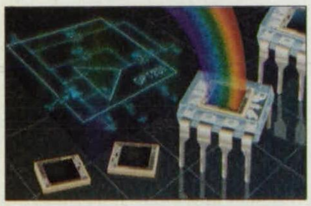
NEW PRODUCT SHOWCASE

SUNX Sensors, West Des Moines, IA, has announced the LA511 **laser beam sensor system**, a Class I laser that complies with 21CFR 1040.10 and 1040.11 FDA regulations. It has a sensing field of 15 mm x 500 mm and offers repeatability of 10 micrometers. The LA511 provides a 1-5 V analog signal and a single NPN transistor set point output.
For More Information Write In No. 700



The MultiSpec™ 257, an **imaging spectrograph** from Oriel Corp., Stratford, CT, uses toroidal optics for spectral imaging over a 25 x 10 mm image area—suitable for acquiring "multi-track" spectra from multiple fiber inputs using CCDs. The instrument has a microprocessor and single, dual, triple, or quadruple grating turrets and integrated filter wheels for automatic grating and filter selection.
For More Information Write In No. 701



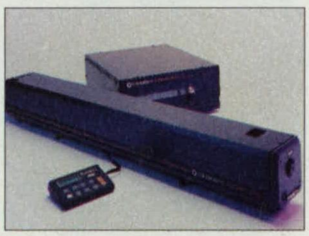
Burr-Brown Corp., Tuscon, AZ, has unveiled the OPT201, a monolithic, **optoelectronic integrated circuit** containing a 0.09" x 0.09" photodiode and a transimpedance amplifier that comprises a precision FET-input op amp and an on-chip metal film resistor. The photodiode operates at zero bias for excellent linearity and low dark current. Features include a MΩ feedback resistor, 2 mV dark errors, and 0.45 A/W (650 nm) responsivity.
For More Information Write In No. 703

The OML series of **micro-miniature laser modules** from LaserMax, Inc., Rochester, NY, integrates a visible laser diode, collimator, and advanced loop power controller into a tiny steel cylindrical tube (7 mm x 50 mm). Laser wavelength is 670 nm with 4.25 mW optical output power (class IIIa). Voltage input is 3-6 VDC at 55 mA, with divergence of approximately 1 mrad.
For More Information Write In No. 702

CODE V **optical design software** from Optical Research Associates, Pasadena, CA, is now available for IBM-compatible PCs. The package features the Global Synthesis™ optimization method to handle the large number of variables and constraints typical of real-world design. Features include nonsequential surface modeling, which allows definition of optical elements in global coordinates and ray path sequences.
For More Information Write In No. 705

Aromat Corp., New Providence, NJ, has announced the LM300, an **integrated analog laser sensor** that provides ten times the resolution of other laser sensors, as well as built-in signal processing, alarm, and communications capabilities. Offering resolution as fine as 8 microinches, the sensor features an RS-232 interface for easy integration into control and data acquisition system, digital inch/mm display of measurement readings, and selectable operating speeds from 25 microseconds to 41 milliseconds.
For More Information Write In No. 706

The DAS-PSP data acquisition system from Magen Scientific Corp., New York, NY, enables ultra-precise measurements of linear as well as angular position coordinates of incident light on a position-sensitive photodiode. It provides fast AC-couples amplifiers (insensitive to ambient light), automatic gain adjustment (256 steps), a bandwidth of 0.2-50 kHz, and eight-channel simultaneous S/H 12-bit fast ADC. The system supports two 2D PSPs simultaneously to measure 3D position with 10 µm accuracy.
For More Information Write In No. 713



Coherent Inc., Palo Alto, CA, has introduced the Innova® 302 small-frame krypton **ion laser** offering violet/UV performance up to 300% higher than current systems. The unit features PowerTrack™, an actively stabilized optical cavity, ModeTrack™, active etalon stabilization that eliminates mode-hops in single-frequency operation, and complete on-board system diagnostics.
For More Information Write In No. 704

Welch Allyn Inspection System Division, Skaneateles Falls, NY, has announced the VideoProbe XL, a **video borescope** merging the portability and simplicity of fiber-optic systems with a high-resolution electronic image. A CCD embedded in the probe's tip delivers a real-time, full-screen color image to a 4" LCD display held in a user's palm. The tip can be steered in four directions by an integrated joystick.
For More Information Write In No. 708

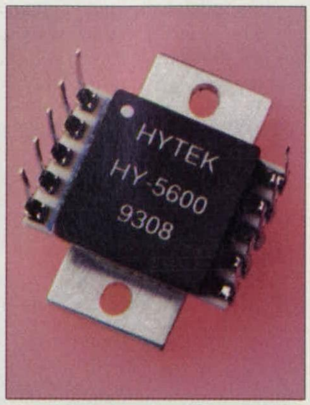
The Model C-8000 **cryogenic gas purifier** from Applied Photonics Inc., Hauppague, NY, extends laser gas life and servicing intervals for industrial excimer lasers. Featuring a high-efficiency cryotrap and heat exchanger for improved beam quality and pulse stability, the C-8000 is designed for unattended operation and long-term reliability. Its electrical system includes a remote computer control option that follows TUV and IBM standards.
For More Information Write In No. 707

The Anocast Division of Anorad Corp., Chagrin Falls, OH, has manufactured a **polymer composite machine base** for CNC Systems' Opticam SX, a high-precision computer-controlled optics machining center. Featuring dynamic stability and structural rigidity, the 80" x 35" x 54" vertical structure provides excellent vibration dampening, noise reduction, and chemical resistance.
For More Information Write In No. 712

Seastar Optics Inc., Seattle, WA, has developed the PF series broadband analog or digital **microwave laser diode module** for optical communications applications. Modulation bandwidths from 100 kHz up to 6.0 GHz are available at 780, 830, 1310, and 1550 nm using F-P and DFB hermetically-sealed laser diodes. Optical isolation and thermoelectric control are included.
For More Information Write In No. 711

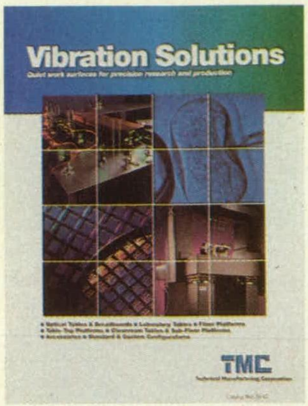
GapMaster™, a handheld laser **measurement system** for gap width and surface mismatch, is available from TMA Technologies Inc., Bozeman, MT. The device captures gap widths up to 0.500" and mismatches up to 0.250" to an accuracy of ± 0.005" on a variety of surfaces and materials. PC-based software eliminates angular alignment problems and resolves complex edges. Results are displayed simultaneously on an LCD at the rear of the unit's head and on a PC screen.
For More Information Write In No. 709

Laser diode products from LiCONIX®, Santa Clara, CA, include drivers for low- and medium-power laser diodes, a thermoelectric cooler controller, and a high-numerical-aperture collimating lens. The LDD200 driver controls diodes requiring up to 160 milliamps; the LDD100 those requiring up to 1.5 amps.
For More Information Write In No. 710



Hytek Microsystems, Carson City, NV, has announced a subminiature **thermoelectric cooler controller** for sensitive electronic components such as diode lasers, ring gyro lasers, photo-optical detectors, quartz crystals, sensors, and low-noise solid-state amplifiers. Precise temperature stability (from -55 °C to ambient, improves the measurement resolution of photodetectors and the measurement accuracy of sensors while prolonging diode laser life and minimizing center frequency drift.
For More Information Write In No. 714

NEW LITERATURE

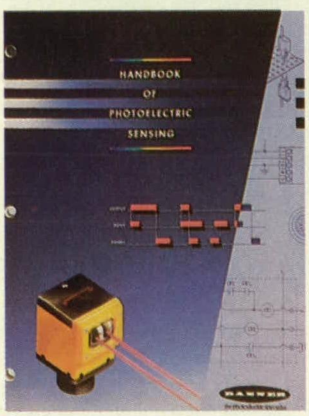


Technical Manufacturing Corp., Peabody, MA, has released a full-color catalog of its **vibration isolation systems, optical tables, platforms, components, and accessories**. Sections describe optical tops, breadboards and supports, lab tables and tabletop platforms, floor platforms, and the MagPneumatic® active vibration isolation systems.

For More Information Write In No. 716

Filters for wavelengths from the near-infrared (1064 nm) to soft x-rays are highlighted in a catalog from Acton Research Corp., Acton, MA. New products include UV filter glass and UV-VIS long wave pass cut-off filters, available in 0.5", 1.0" and 2.0" diameters as well as 2" x 2" squares. Also detailed are narrow and broadband UV, neutral density, reflective, bandpass, and stray-light reducing filters.

For More Information Write In No. 718

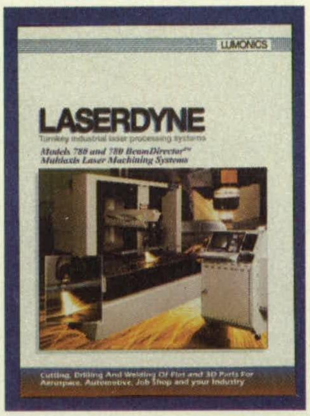


A 240-page **photoelectric sensing** handbook from Banner Engineering Corp., Minneapolis, MN, discusses sensing theory and provides in-depth technical information on sensor selection. Topics include sensing modes, sensor sizes and types, electrical and environmental considerations, interfaces, sensing logic, and troubleshooting.

For More Information Write In No. 722

Newport/Klinger, Irvine, CA, has released a 32-page catalog of its new **optics and laser equipment**, including vibration control tables, translation stages, optic mounts, fiber optics tools, actuators, and kits. Featured products include the Neutralizer™ active vibration control system, which offers the highest level of three- or six-axis active vibration control available for SEMs, TEMs, semiconductor manufacturing equipment, and sensitive analytical instruments; and the ULTRAlign™ series of positioning components for single-mode fiber positioning with submicron positioning accuracy and drift-free stability.

For More Information Write In No. 723



A brochure from the Laserdyne Division of Lumonics Corp., Eden Prairie, MN, describes enhancements to its models 780 and 780 BeamDirector™ multi-axis **laser machining systems**. These include Selectable Seek™, which permits automatic focusing along the axis of the laser beam or in any user-specified direction, and digital signal processing for 25-50 times faster servo update times than previously attainable. The publication provides easy to understand techniques for cutting, drilling, and welding flat and 3D parts.

For More Information Write In No. 715

A technical brochure from Morton International Inc., Woburn, MA, details optical, mechanical, thermal, and physical properties of its **infrared transmitting materials**: zinc selenide (ZnSe), zinc sulfide (ZnS), CLEARTRAN™ (water clear zinc sulfide), and TUFTRAN™ (ZnSe with ZnS layer). These high-purity materials, produced by chemical vapor deposition, are used in windows and lenses for temperature sensing, thermal imaging, and laser systems.

For More Information Write In No. 726

Hughes Aircraft Co., Malibu, CA, has released data sheets and application notes on its CROSSATRON® **modulator switches**, which have several advantages over thyratrons for laser applications. The device's cold cathode eliminates both the need for heater power and for the failure mechanisms associated with a hot cathode device. The CROSSATRON has a longer life expectancy (up to ten times) and higher PRF capability than both thyratron and spark gap switches.

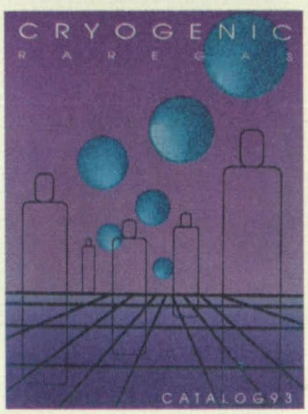
For More Information Write In No. 717

A 160-page catalog from Optometrics USA, Inc., Ayer, MA, showcases its range of **optical components and instruments**. New products include microplate readers and washers, an instrument for measuring SPF values in lotions and creams, and a range of gratings and reticles for metrology. The catalog also features UV/Vis and NIR spectrophotometers.

For More Information Write In No. 719

A 12-page catalog from 3M Specialty Optical Fibers, West Haven, CT, describes **specialty single-mode fibers and fiber-based components** operating at wavelengths from 630 to 1550 nm. New products include high single-mode fibers, single-mode fibers for non-telecommunications wavelengths, single-polarization fibers, and polarization-maintaining fibers, cables, couplers, and end terminations.

For More Information Write In No. 724

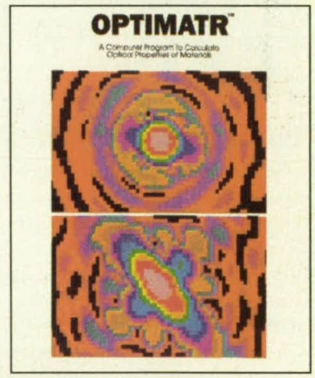


Xenon, krypton, neon, and other high-purity **gases for lasers**, are described in a catalog from Cryogenic Rare Gas, Hanahan, SC. Excimer laser gas mixtures, both fluorine and hydrogen chloride, are highlighted, as well as gas handling equipment, flowmeters, regulators, and isotopes.

For More Information Write In No. 720

A selection guide for **optical radiation measuring instruments** is available from EG&G Gamma Scientific, San Diego, CA. The flexible components can be custom-configured into computer- or manually-controlled systems. Products include light sources, receptors, couplers, electric shutters and adaptors, spectral selectors, detectors, radiometers/photometers, and scanning controls.

For More Information Write In No. 725



OPTIMATR, **software for computing the optical properties of materials** with potential for use in optical systems, is described in a brochure from ARSoftware Corp., Landover, MD. With 85 materials in its database, the program uses physical principles to compute index of refraction, absorption coefficient, and scattering coefficient as a function of wavenumber or wavelength and temperature.

For More Information Write In No. 728

ILX Lightwave, Bozeman, MT, has published a catalog of **electro- and fiber-optic products**, including laser measurement devices and diode controls. Product line additions include the ILX WaveHead wavelength meter, which eliminates special fixturing and coupling optics, and the FPM-8200 Fiber Optic Power meter, accurate to 2.5% with 0.1 pW resolution.

For More Information Write In No. 727

A 100-page **optical tables and breadboards** guide from Melles Griot, Irvine, CA, describes vibration-control technology and a range of optical tabletops, vibration isolation systems, optical breadboards, and workstations. New optical tabletops incorporate high-strength roll-formed threads, provide the lowest relative tabletop motion available, and feature the TurboClean™ sealing system for easy cleanup.

For More Information Write In No. 721

OPTICS

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